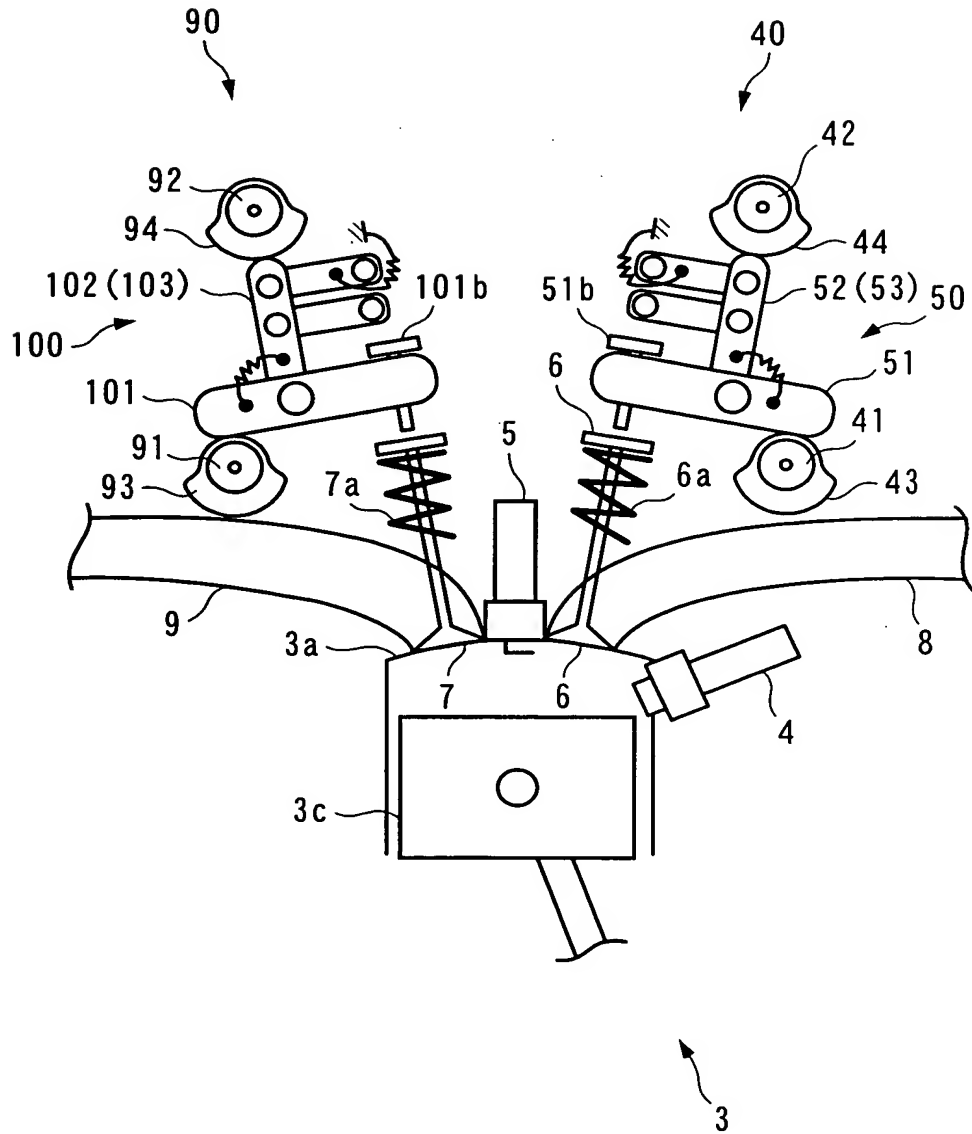
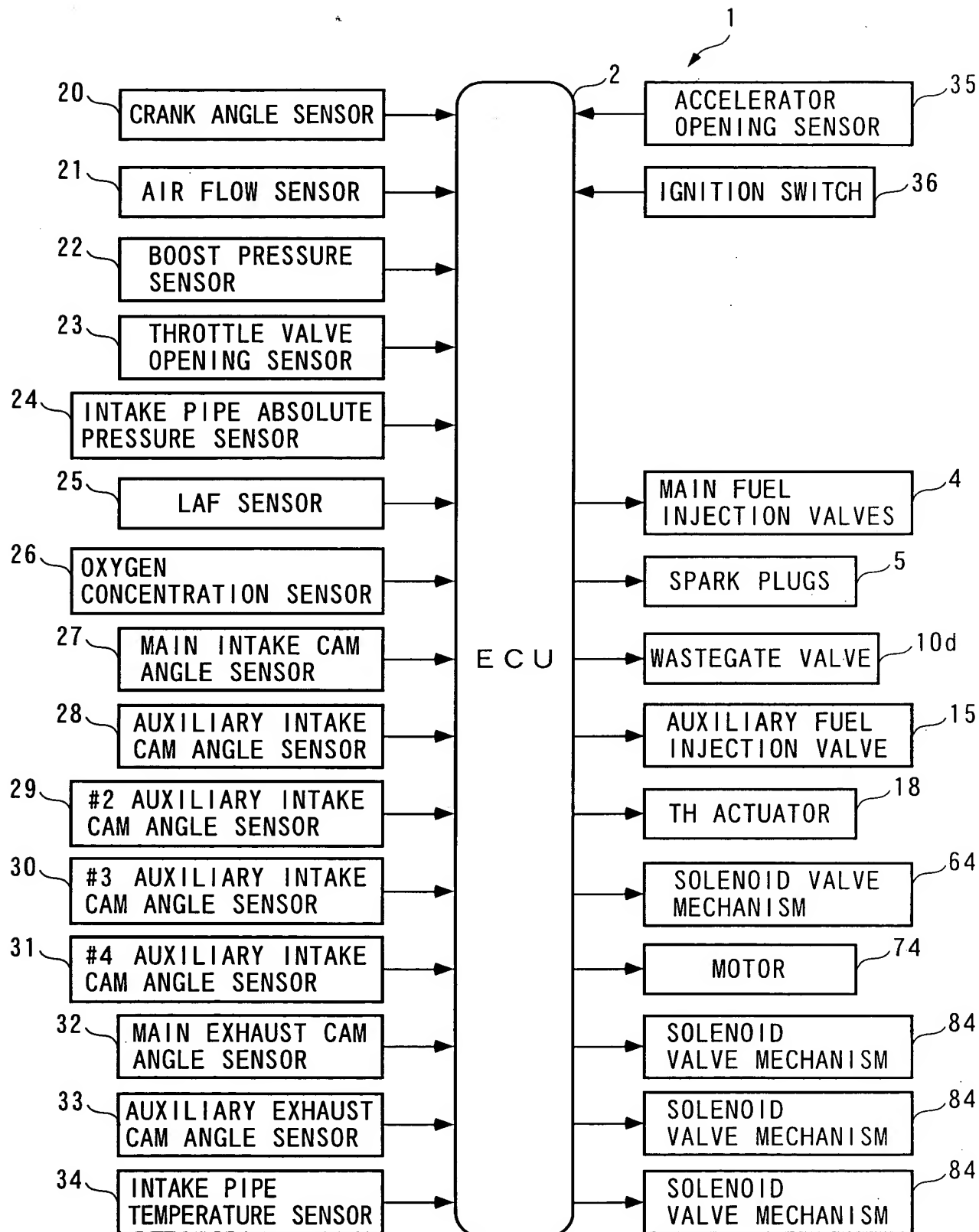


F I G . 2



F I G . 3



F I G. 4

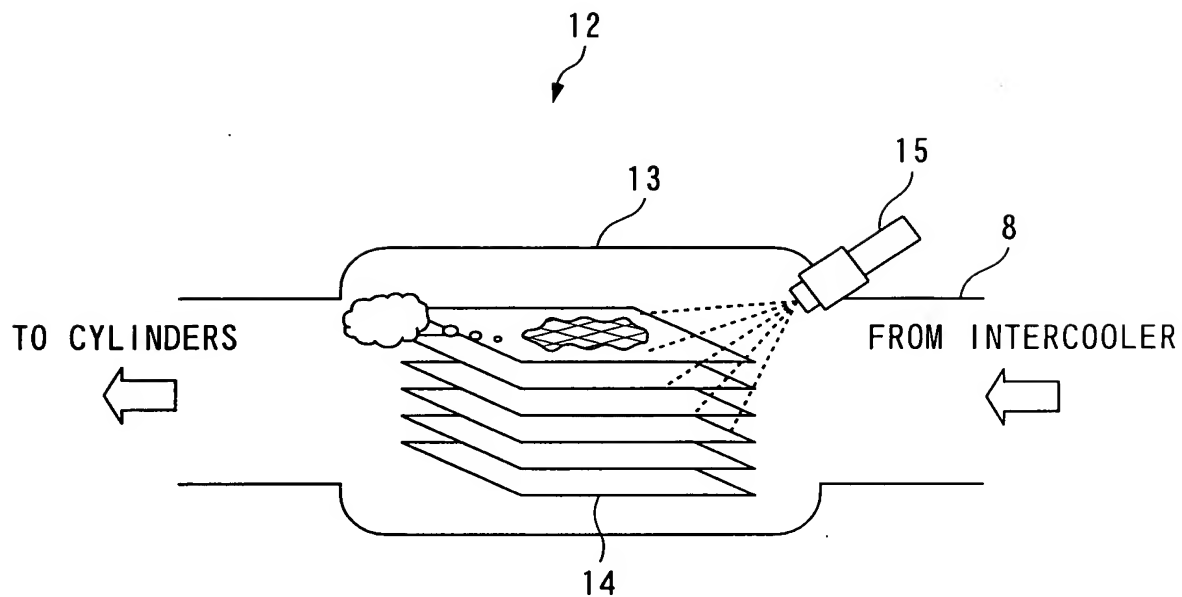
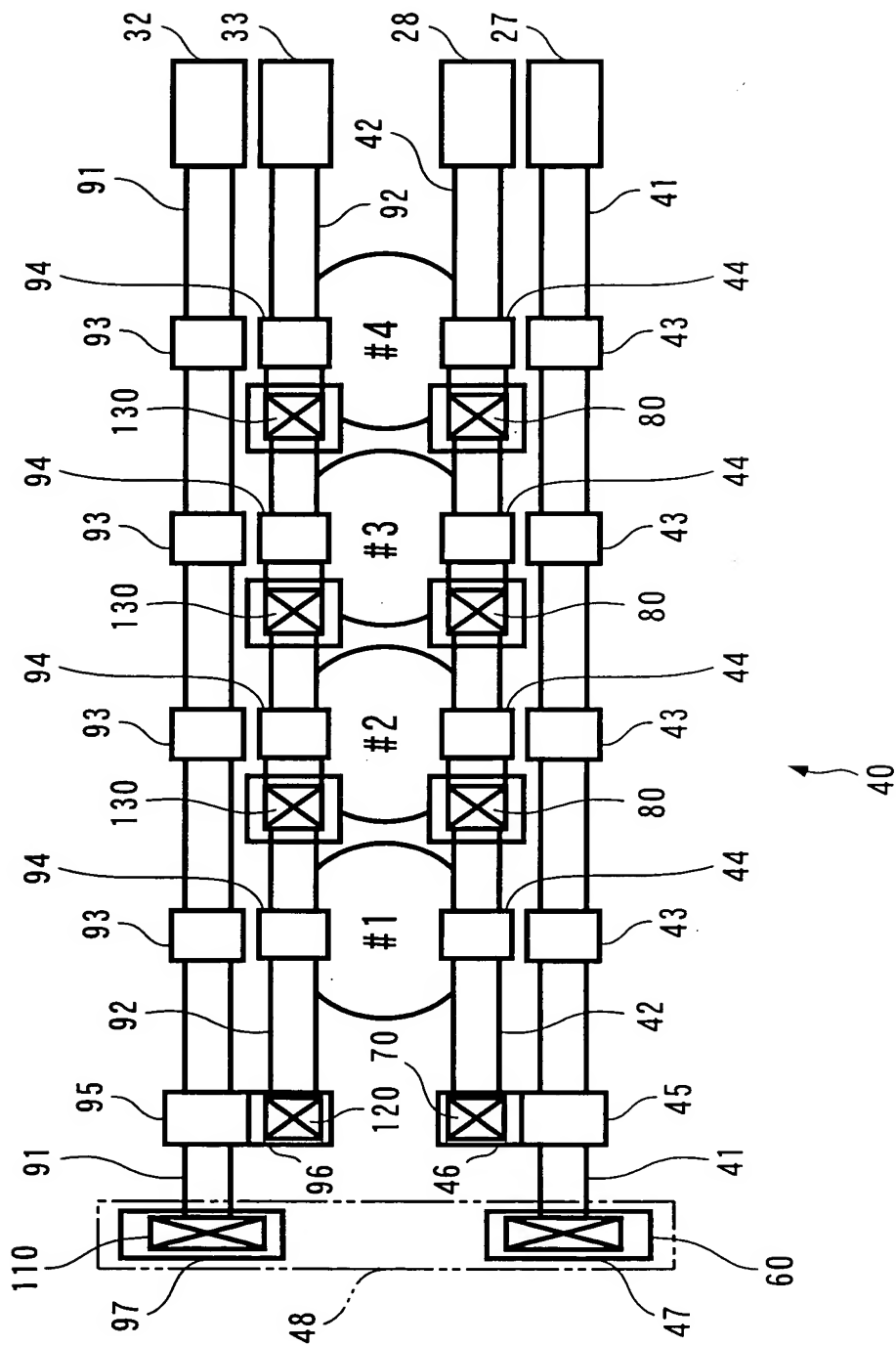


FIG. 5



F I G. 6

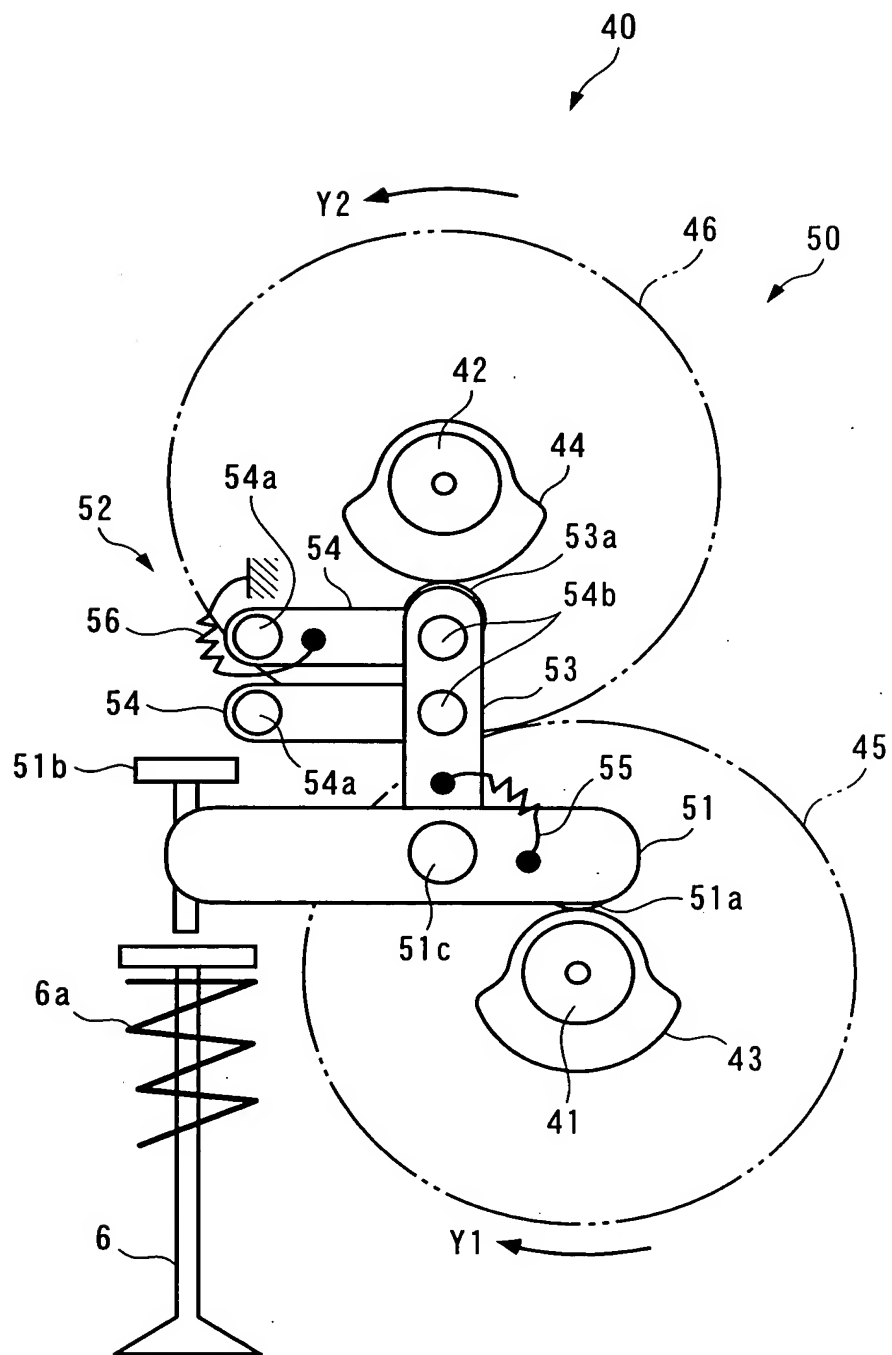
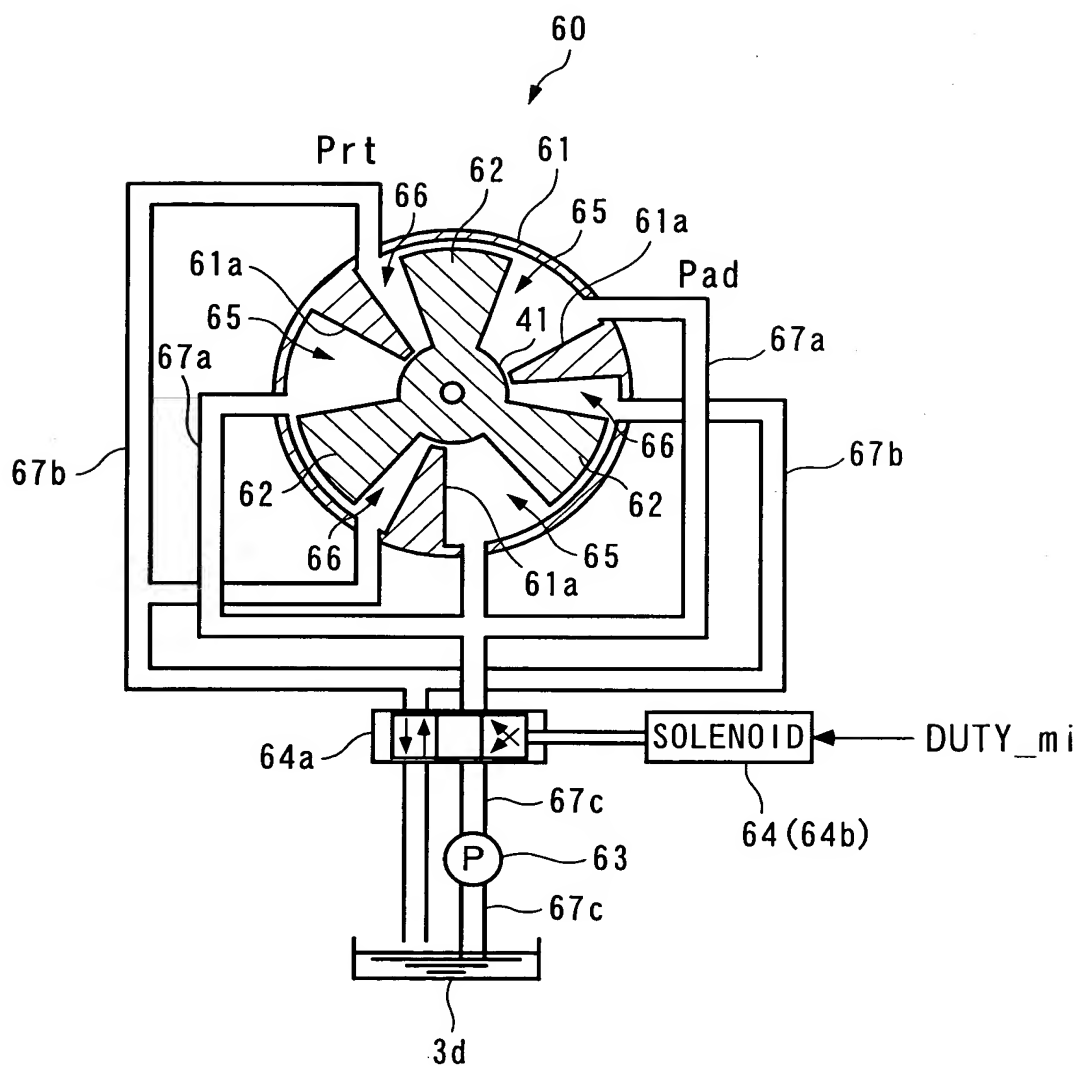
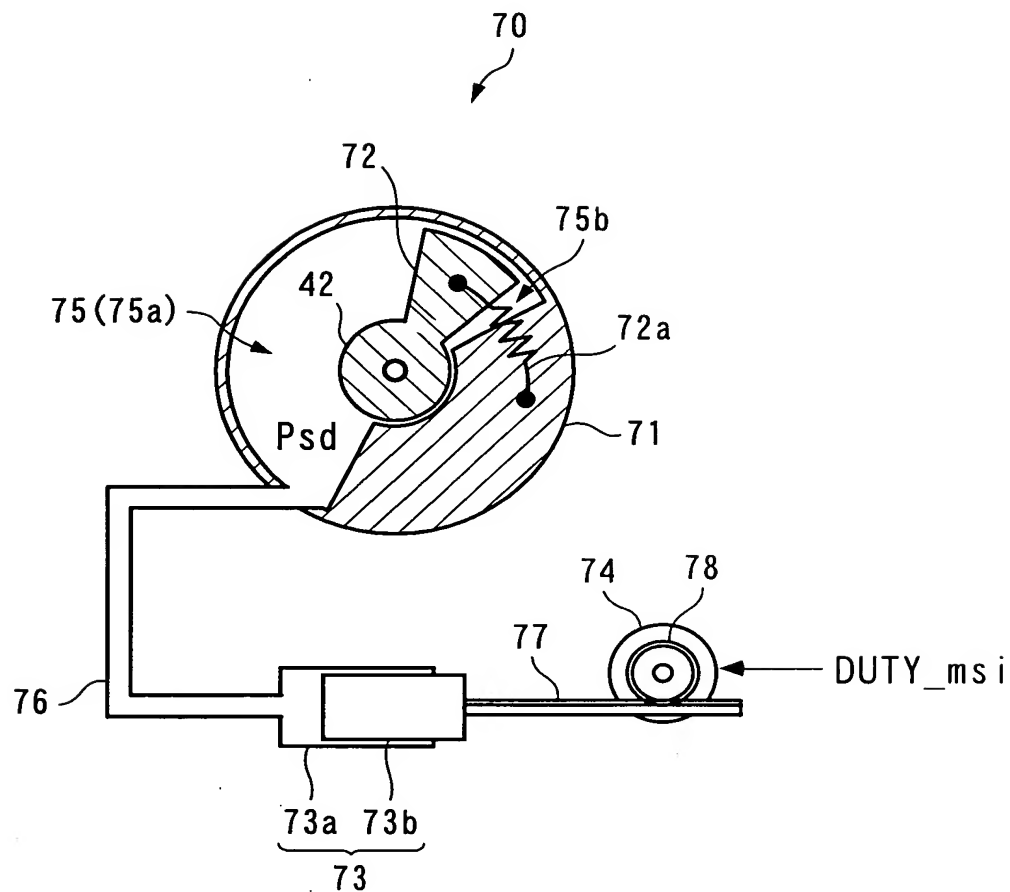


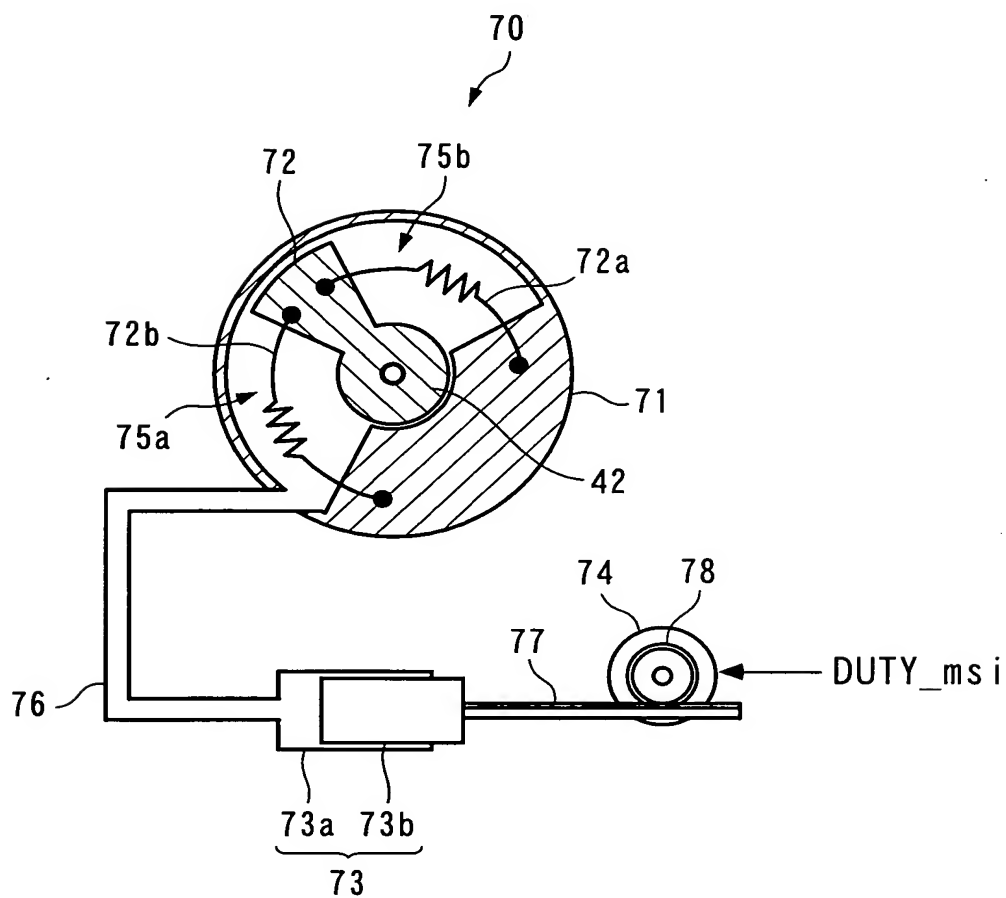
FIG. 7



F I G. 8



F I G. 9



F I G. 1 0

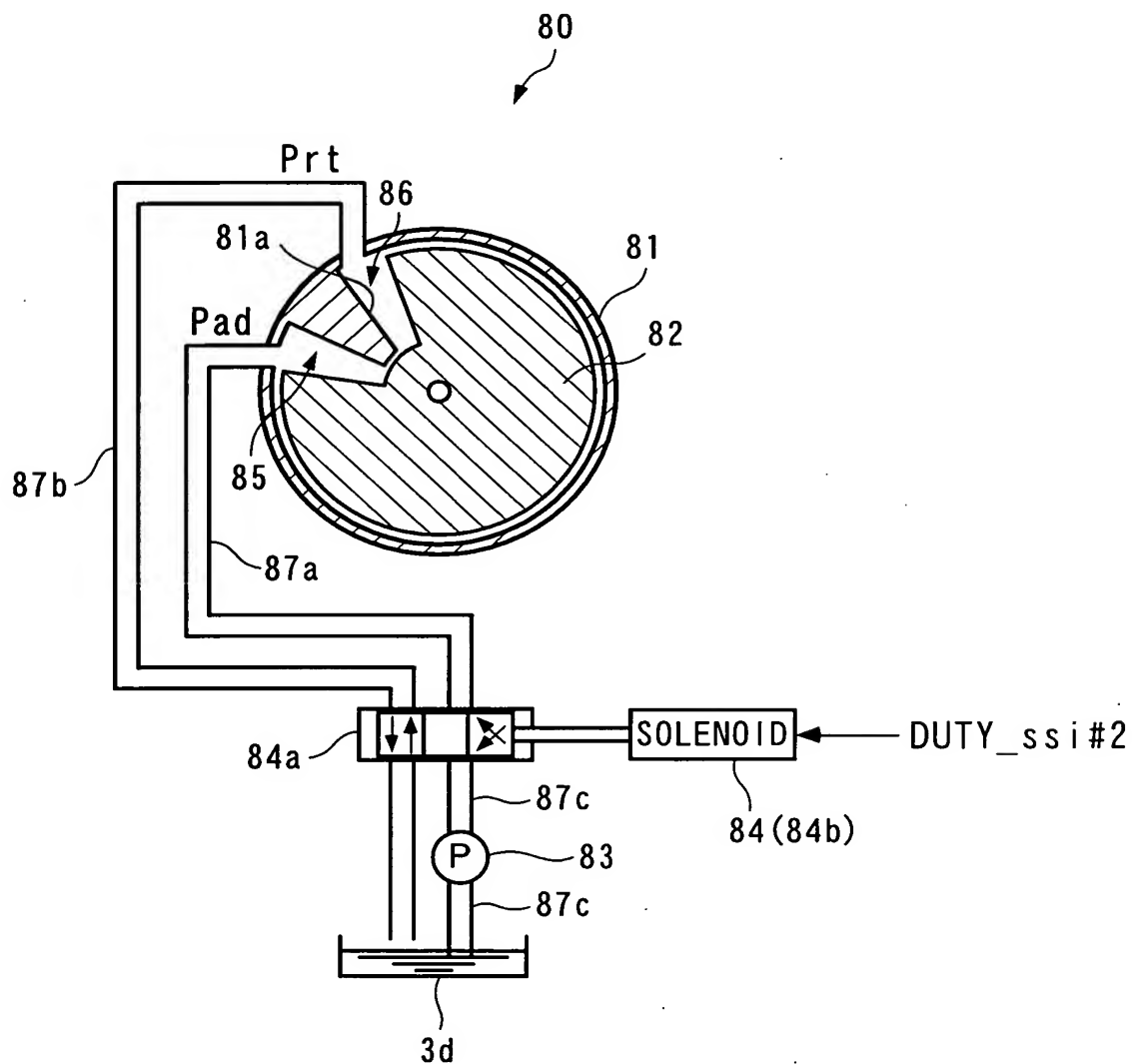
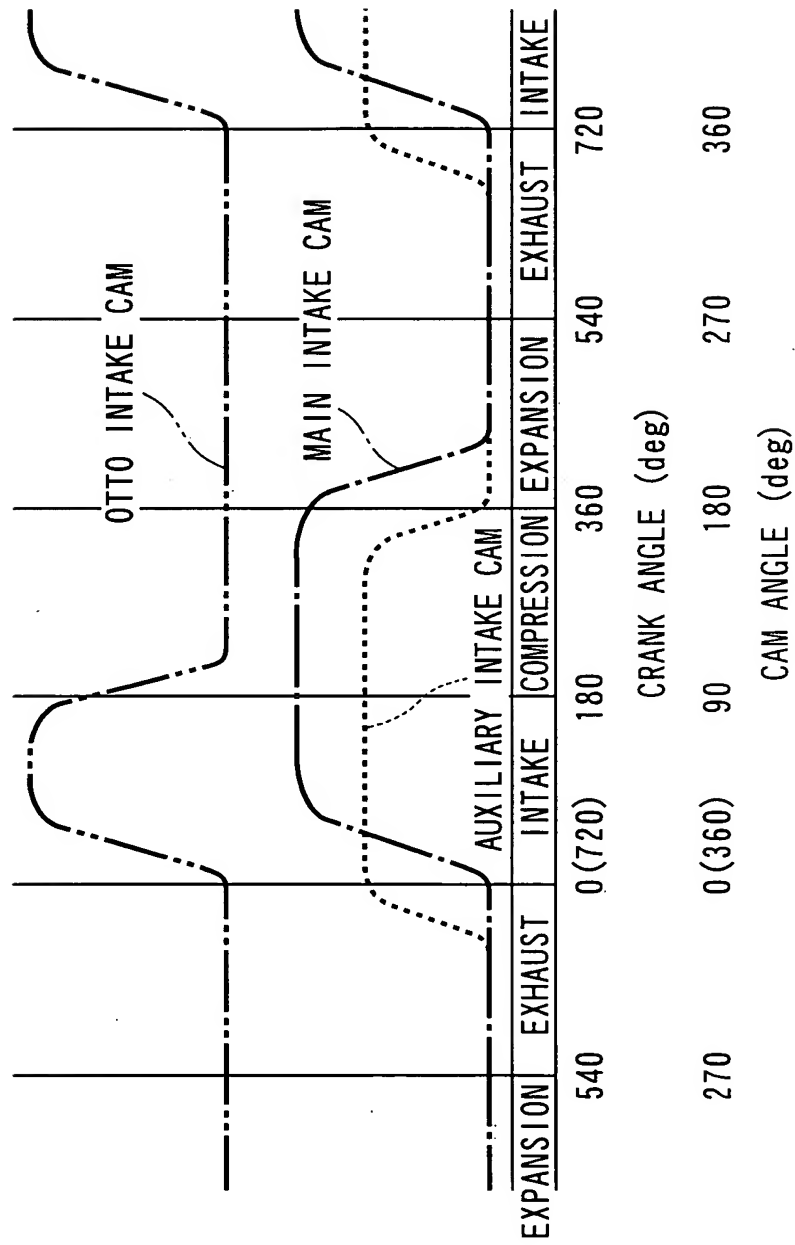
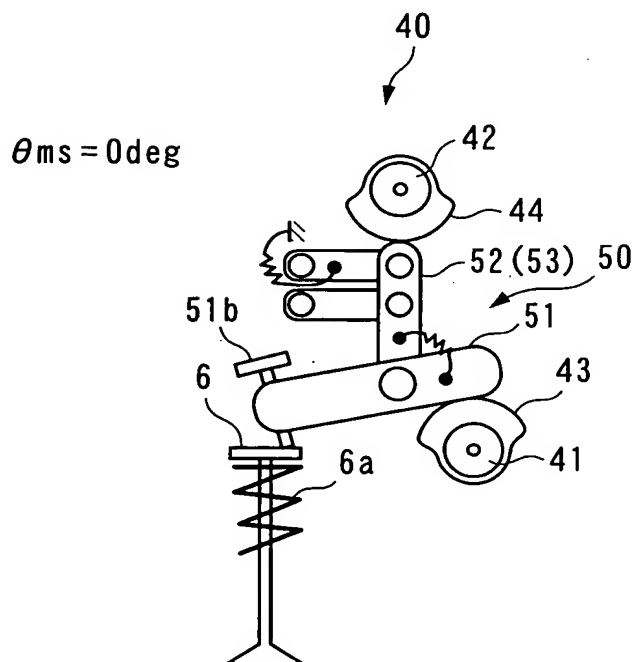


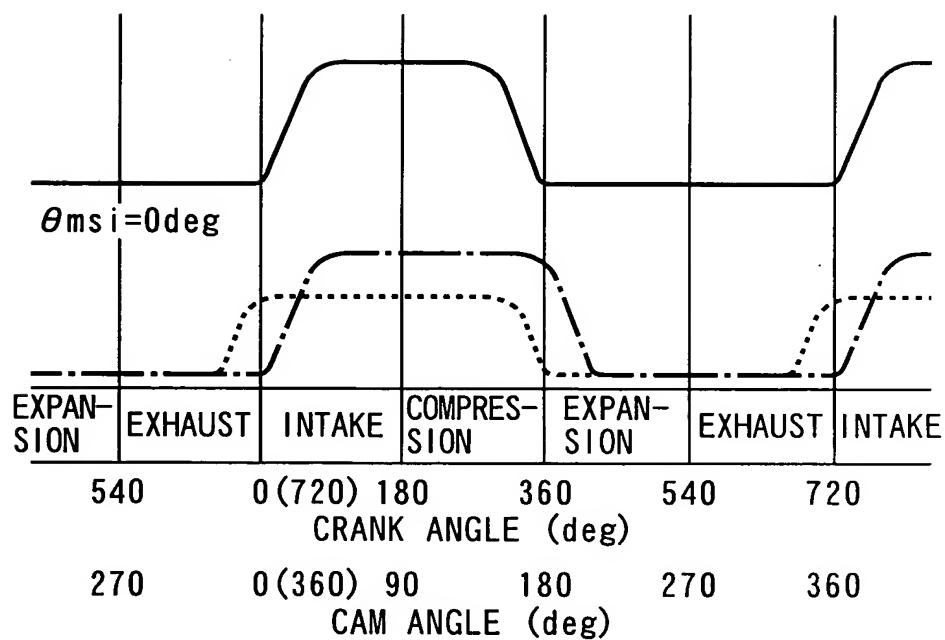
FIG. 11



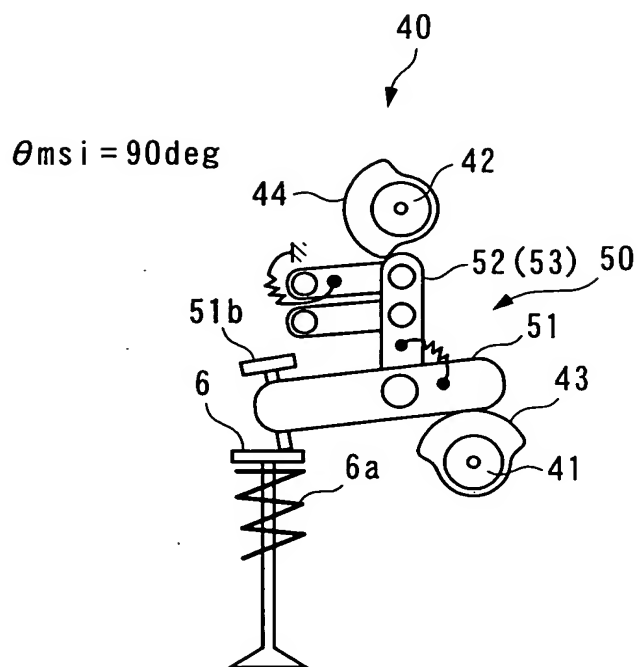
F I G. 1 2 A



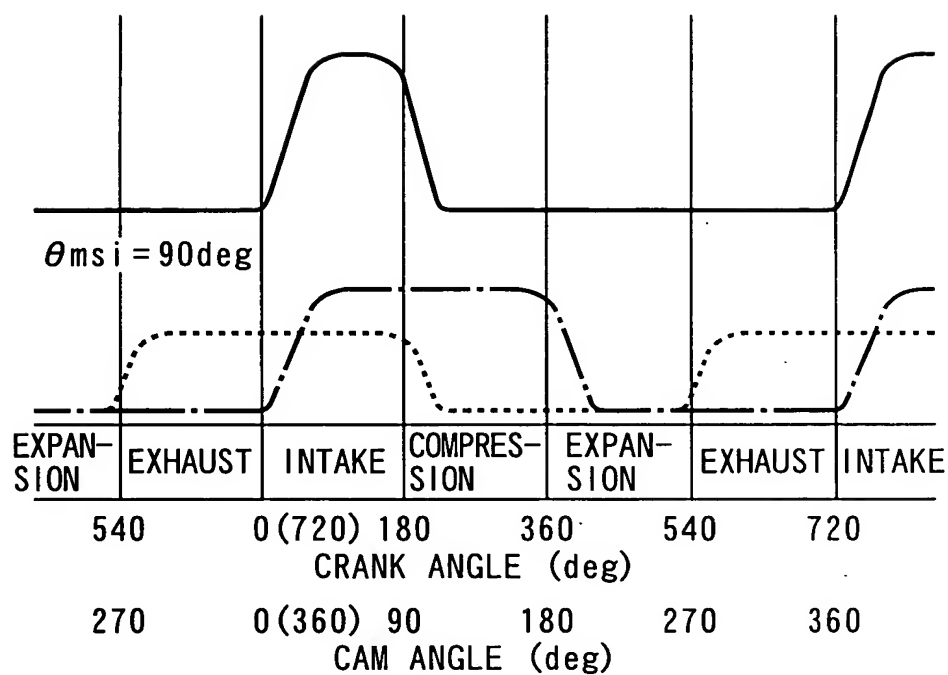
F I G. 1 2 B



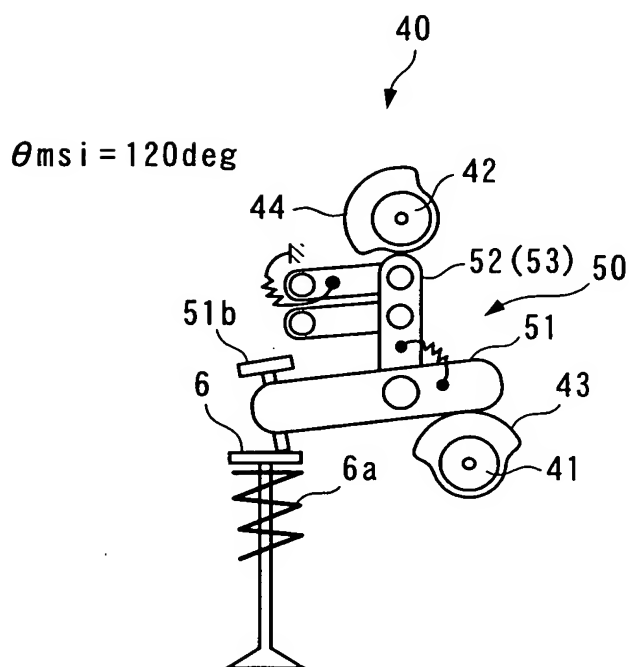
F I G. 1 3 A



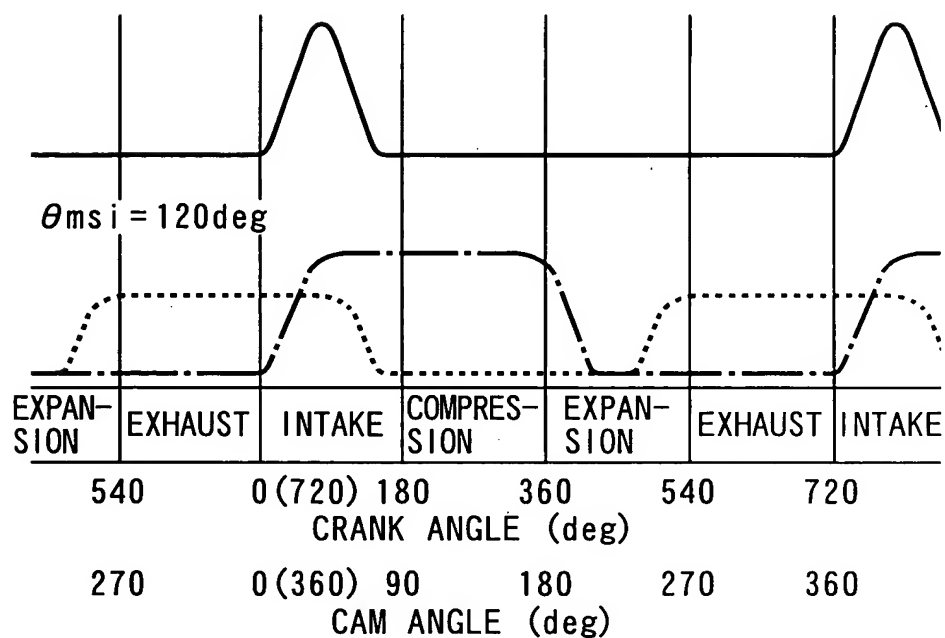
F I G. 1 3 B



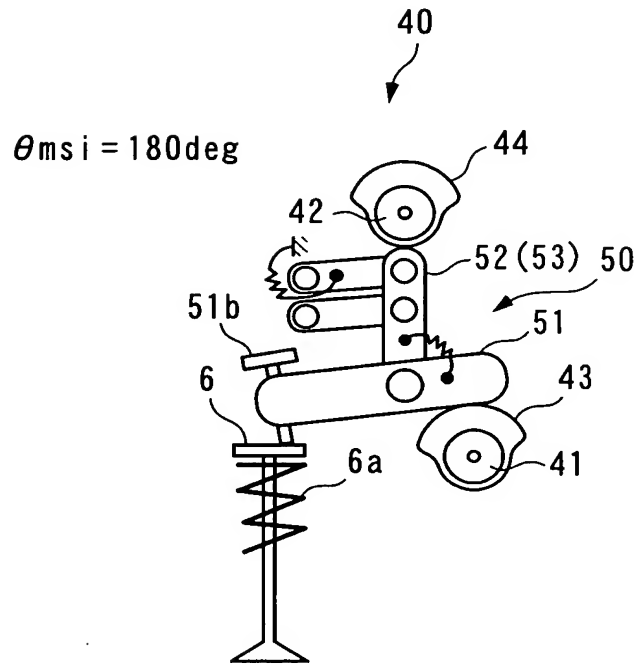
F I G . 1 4 A



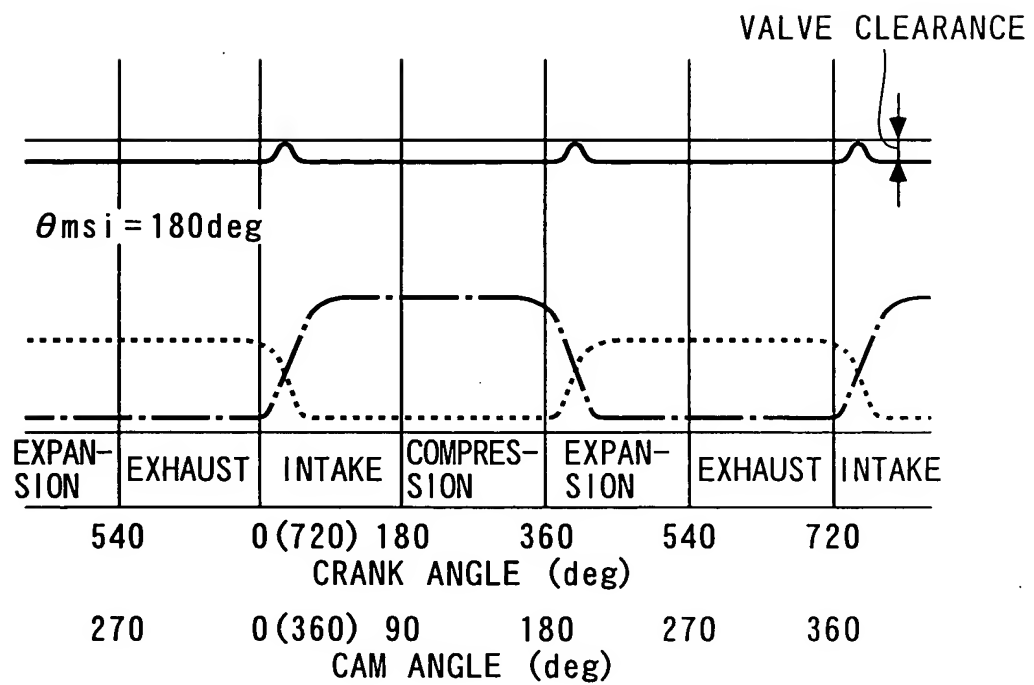
F I G . 1 4 B



F I G. 1 5 A



F I G. 1 5 B



F I G. 1 6

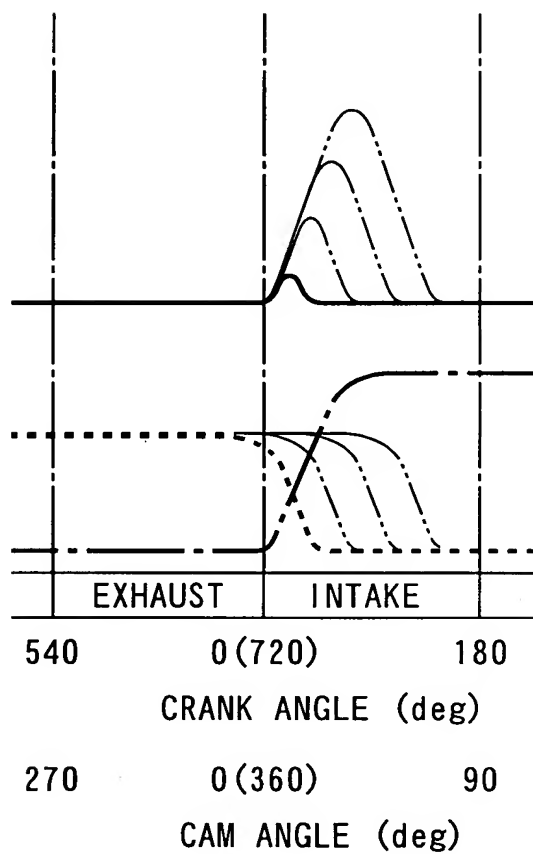
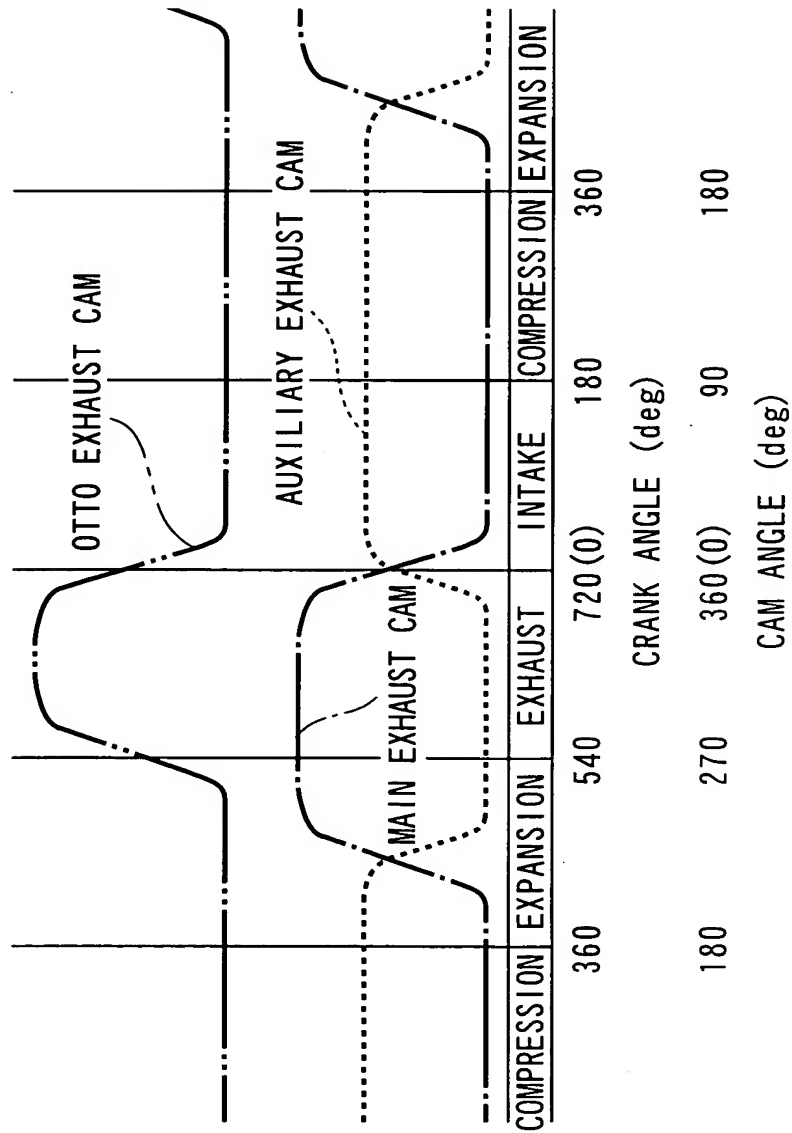
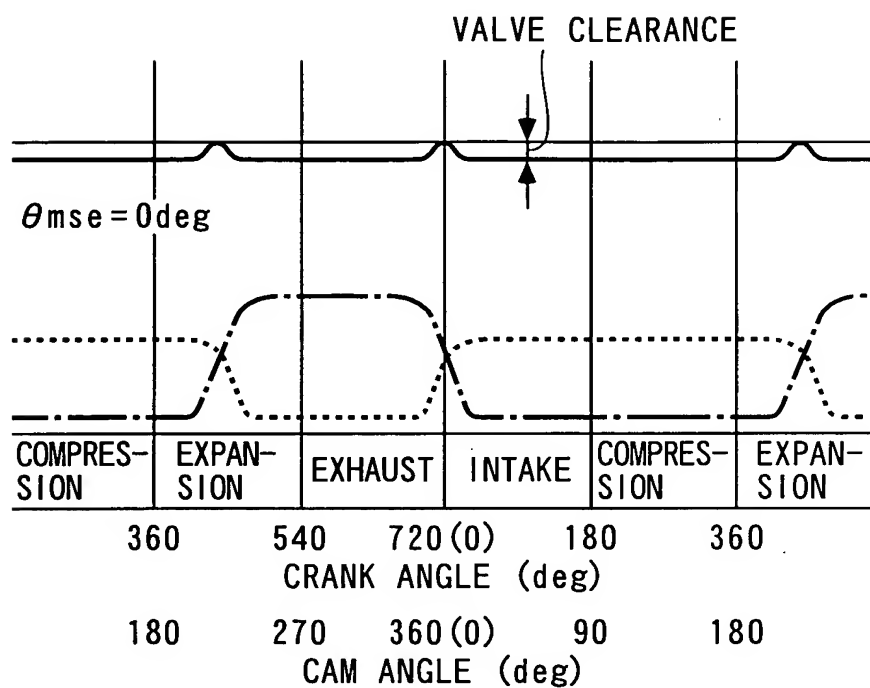


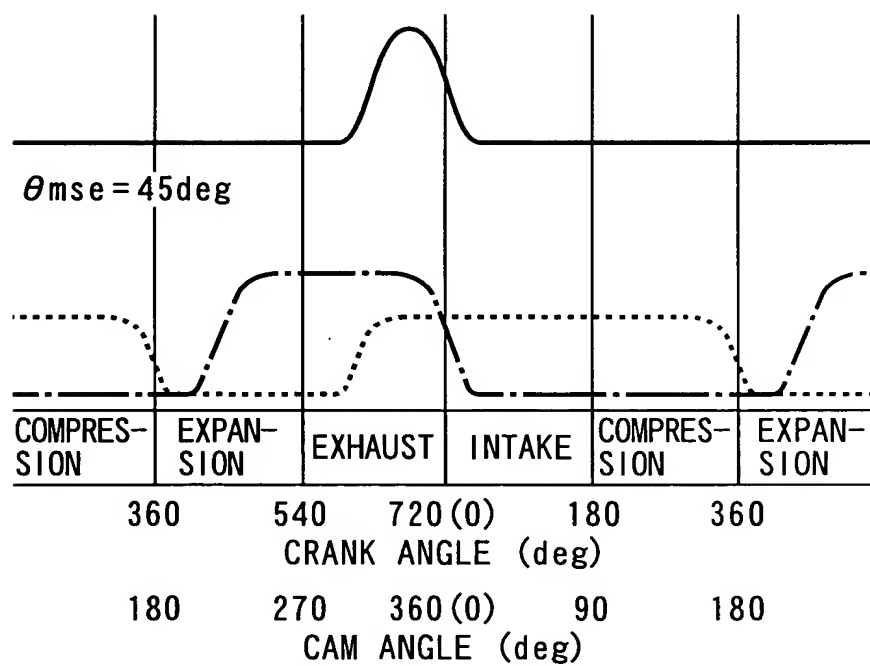
FIG. 17



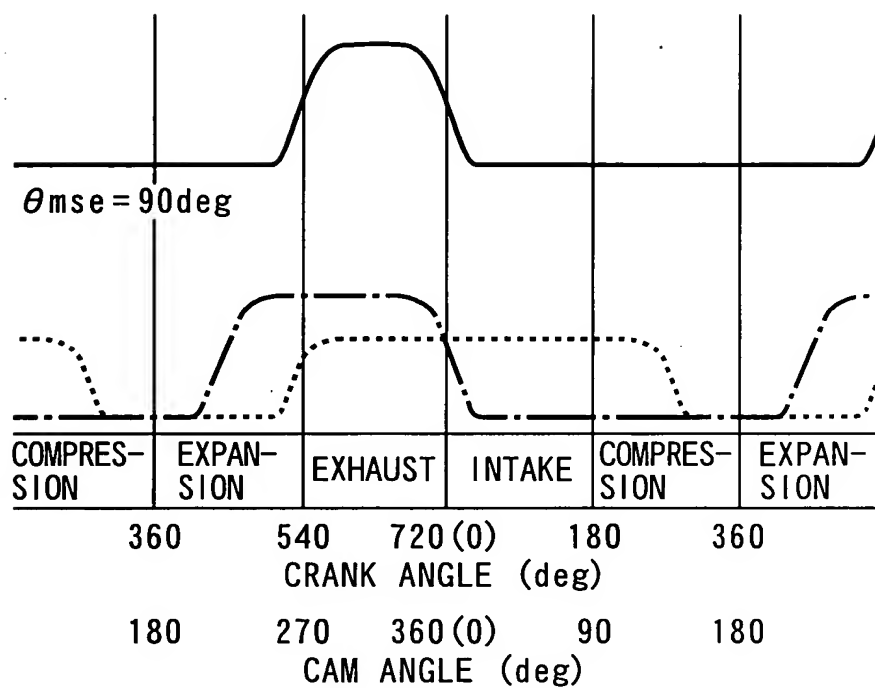
F I G. 1 8



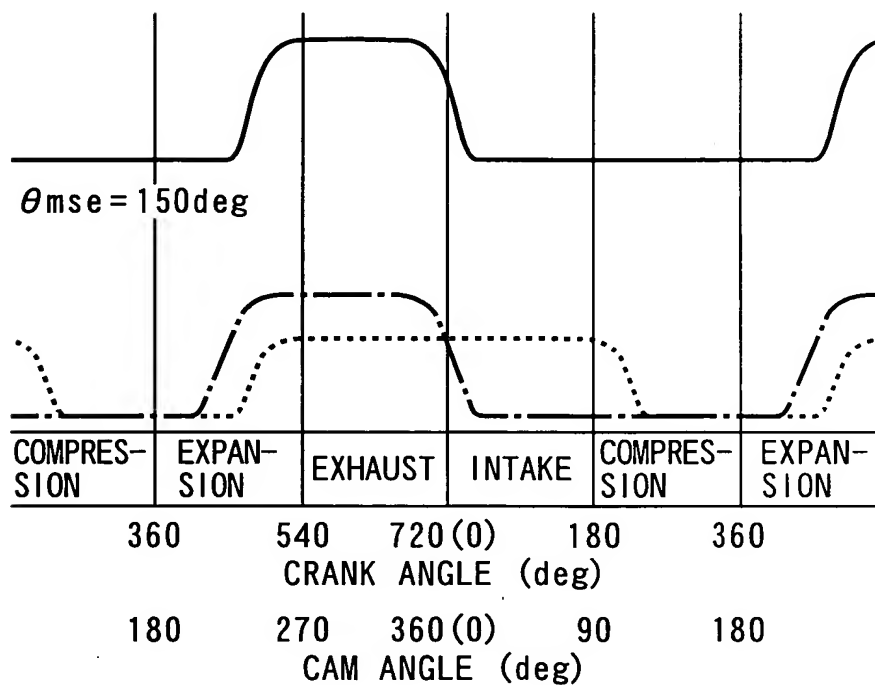
F I G. 1 9



F I G . 2 0



F I G . 2 1



F I G . 2 2

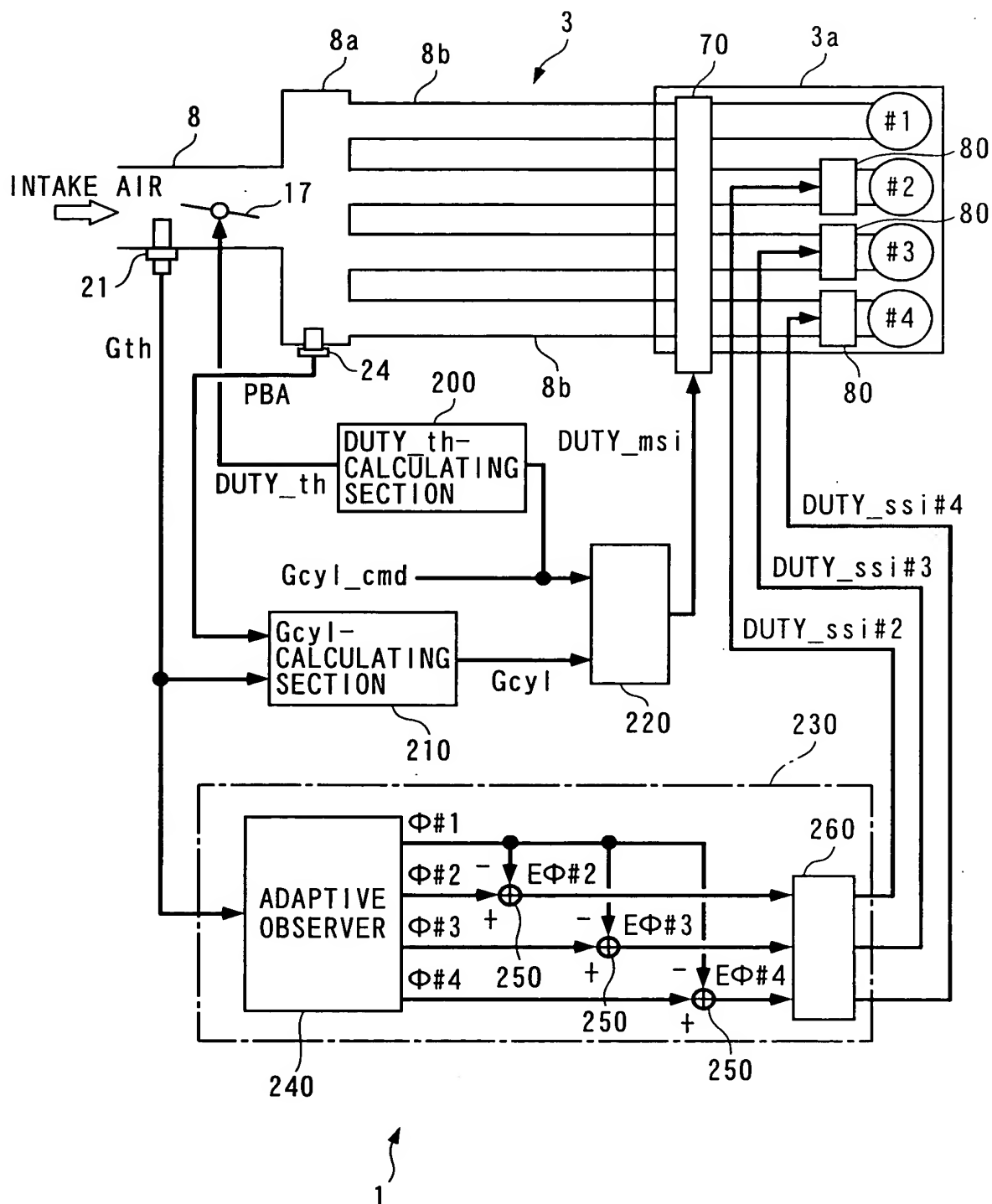
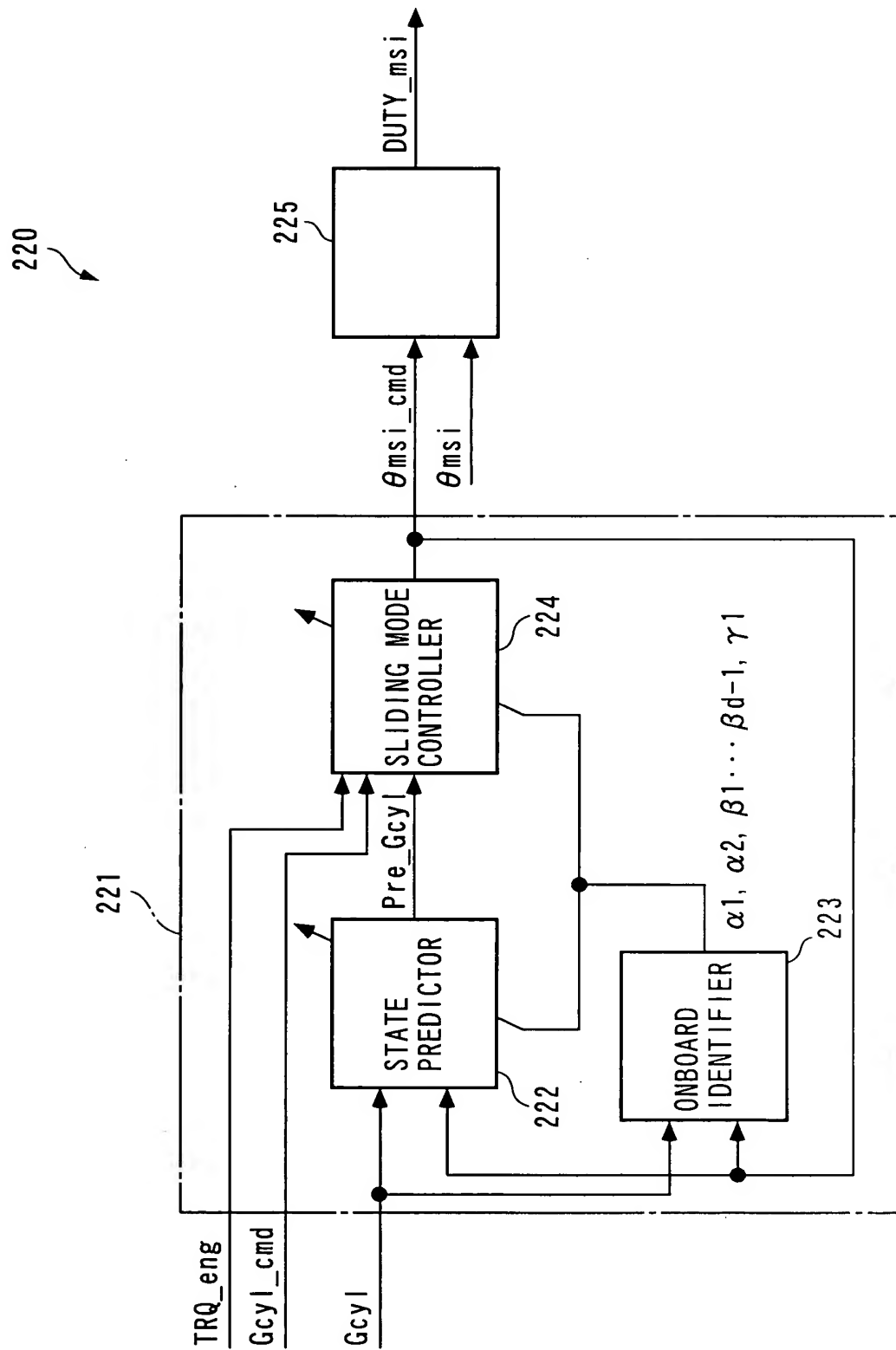


FIG. 23



F I G. 2 4

$$G_{cyl}(n) = G_{th}(n) - \frac{VB \cdot [PBA(n) - PBA(n-1)]}{R \cdot TB} \quad \dots\dots (1)$$

$$G_{cyl}(n) = a1 \cdot G_{cyl}(n-1) + a2 \cdot G_{cyl}(n-2) + b1 \cdot \theta_{msi}(n-d) \quad \dots\dots (2)$$

$$G_{cyl}(n+d-1) = a1 \cdot G_{cyl}(n+d-2) + a2 \cdot G_{cyl}(n+d-3) + b1 \cdot \theta_{msi}(n-1) \quad \dots\dots (3)$$

$$A = \begin{bmatrix} a1 & a2 \\ 1 & 0 \end{bmatrix} \quad \dots\dots (4)$$

$$B = \begin{bmatrix} b1 \\ 0 \end{bmatrix} \quad \dots\dots (5)$$

$$\begin{aligned} G_{cyl}(n+d-1) = & \alpha1 \cdot G_{cyl}(n) + \alpha2 \cdot G_{cyl}(n-1) \\ & + \beta1 \cdot \theta_{msi}(n-1) + \beta2 \cdot \theta_{msi}(n-2) \\ & + \dots + \beta_{d-1} \cdot \theta_{msi}(n-d+1) \end{aligned} \quad \dots\dots (6)$$

$\alpha1$: FIRST-ROW FIRST-COLUMN ELEMENT OF A^{d-1}
 $\alpha2$: FIRST-ROW SECOND-COLUMN ELEMENT OF A^{d-1}
 β_j : FIRST-ROW ELEMENT OF $A^{j-1} B$ ($j=0 \sim d-1$)

$$\begin{aligned} Pre_G_{cyl}(n) = & \alpha1 \cdot G_{cyl}(n) + \alpha2 \cdot G_{cyl}(n-1) \\ & + \beta1 \cdot \theta_{msi}(n-1) + \beta2 \cdot \theta_{msi}(n-2) \\ & + \dots + \beta_{d-1} \cdot \theta_{msi}(n-d+1) + \gamma1 \\ \doteq & G_{cyl}(n+d-1) \end{aligned} \quad \dots\dots (7)$$

F I G. 2 5

$$\theta_s(n) = \theta_s(n-1) + KPs(n) \cdot ide(n) \quad \dots\dots (8)$$

$$KPs(n) = \frac{Ps(n) \cdot \zeta_s(n)}{1 + \zeta_s(n)^T \cdot Ps(n) \cdot \zeta_s(n)} \quad \dots\dots (9)$$

$$Ps(n+1) = \frac{1}{\lambda_1} \left[I - \frac{\lambda_2 \cdot Ps(n) \cdot \zeta_s(n) \cdot \zeta_s(n)^T}{\lambda_1 + \lambda_2 \cdot \zeta_s(n)^T \cdot Ps(n) \cdot \zeta_s(n)} \right] Ps(n) \quad \dots\dots (10)$$

I : UNIT MATRIX OF ORDER d+2
λ₁, λ₂ : WEIGHTING PARAMETER

$$\begin{aligned} ide(n) &= Pre_Gcyl(n-d+1) - Gcyl(n) \\ &= \theta_s(n-1)^T \cdot \zeta_s(n) - Gcyl(n) \end{aligned} \quad \dots\dots (11)$$

$$\theta_s(n)^T = [\alpha_1, \alpha_2, \beta_1, \beta_2, \dots, \beta_{d-1}, \gamma_1] \quad \dots\dots (12)$$

$$\begin{aligned} \zeta_s(n)^T &= [Gcyl(n-d), Gcyl(n-d-1), \\ &\quad \theta_{msi}(n-d), \theta_{msi}(n-d-1), \dots, \theta_{msi}(n-2d+2), 1] \end{aligned} \quad \dots\dots (13)$$

F I G. 2 6

$$\begin{aligned} Gcyl(n+d) = & \alpha 1 \cdot Gcyl(n+1) + \alpha 2 \cdot Gcyl(n) \\ & + \beta 1 \cdot \theta msi(n) + \beta 2 \cdot \theta msi(n-1) \\ & + \cdots + \beta d-1 \cdot \theta msi(n-d+2) + \gamma 1 \end{aligned} \quad \cdots \cdots (14)$$

$$Es(n) = Gcyl(n) - Gcyl_cmd(n) \quad \cdots \cdots (15)$$

$$\sigma s(n) = Es(n) + Ss \cdot Es(n-1) \quad \cdots \cdots (16)$$

$$-1 < Ss < 0 \quad \cdots \cdots (17)$$

$$\begin{aligned} \theta msi_cmd(n) &= Uspas(n) \\ &= Ueq(n) + Urch(n) + Uvt(n) \end{aligned} \quad \cdots \cdots (18)$$

$$\begin{aligned} Ueq(n) = & \frac{1}{\beta 1} \{ Pre_Gcyl(n) + Ss \cdot Pre_Gcyl(n-1) \\ & - \alpha 1 \cdot Pre_Gcyl(n-d+1) - \alpha 2 \cdot Gcyl(n) \\ & - \beta 2 \cdot \theta msi(n-1) - \cdots - \beta d-1 \cdot \theta msi(n-d+2) - \gamma 1 \\ & + Gcyl_cmd(n+d) + (Ss-1) \cdot Gcyl_cmd(n+d-1) \\ & - Ss \cdot Gcyl_cmd(n+d-2) \} \end{aligned} \quad \cdots \cdots (19)$$

$$Urch(n) = \frac{-F}{\beta 1} \cdot \sigma s(n+d-1) \quad \cdots \cdots (20)$$

F : REACHING LAW GAIN (0 < F < 2)

$$Uvt(n) = \theta msi_base(n) \quad \cdots \cdots (21)$$

F I G. 2 7

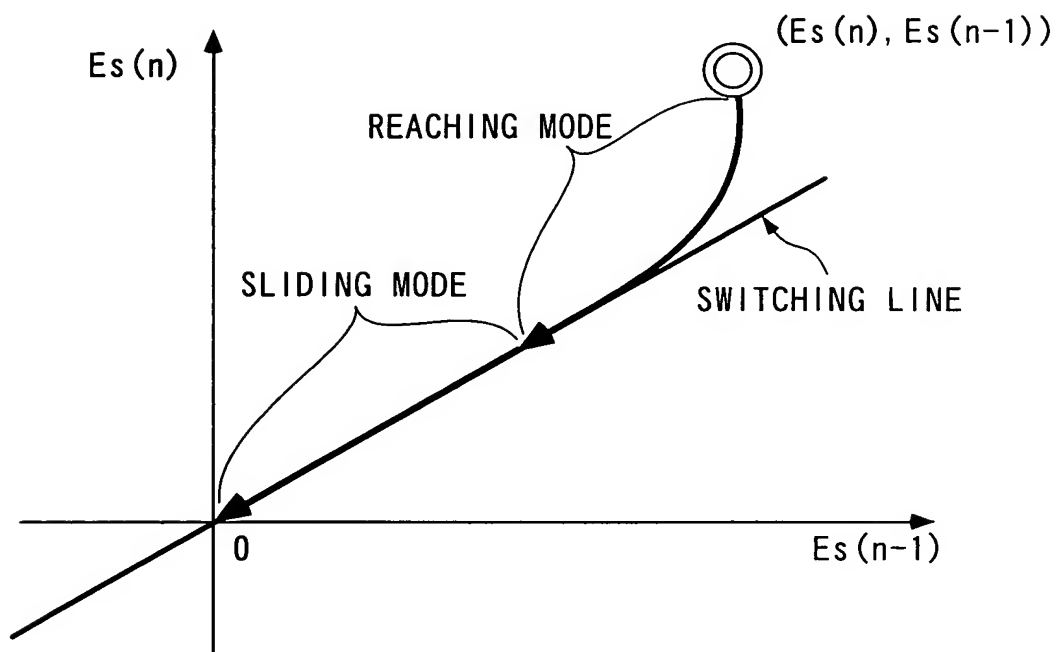
$$\sigma s(n+d) = \sigma s(n+d-1) \quad \dots (22)$$

$$Es(n+d) + Ss \cdot Es(n+d-1) = Es(n+d-1) + Ss \cdot Es(n+d-2) \quad \dots (23)$$

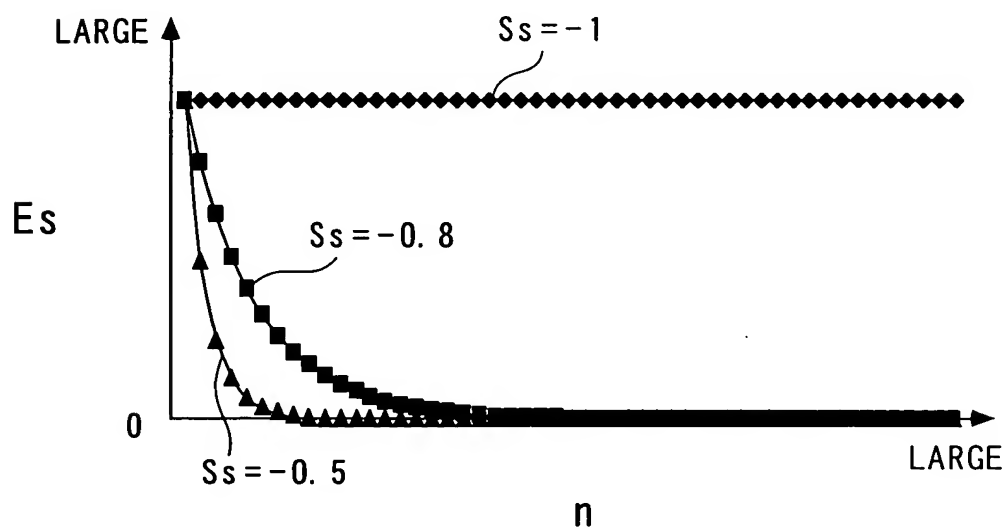
$$\begin{aligned} & \alpha 1 \cdot Gcyl(n+1) + \alpha 2 \cdot Gcyl(n) + \beta 1 \cdot \theta msi(n) + \beta 2 \cdot \theta msi(n-1) \\ & + \dots + \beta d-1 \cdot \theta msi(n-d+2) + \gamma 1 - Gcyl_cmd(n+d) \\ & + Ss \cdot Gcyl(n+d-1) - Ss \cdot Gcyl_cmd(n+d-1) \\ & = Gcyl(n+d-1) - Gcyl_cmd(n+d-1) \\ & + Ss \cdot Gcyl(n+d-2) - Ss \cdot Gcyl_cmd(n+d-2) \quad \dots (24) \end{aligned}$$

$$\begin{aligned} \theta msi(n) = \frac{1}{\beta 1} \{ & Gcyl(n+d-1) + Ss \cdot Gcyl(n+d-2) \\ & - \alpha 1 \cdot Gcyl(n+1) - \alpha 2 \cdot Gcyl(n) \\ & - \beta 2 \cdot \theta msi(n-1) - \dots - \beta d-1 \cdot \theta msi(n-d+2) - \gamma 1 \\ & + Gcyl_cmd(n+d) + (Ss-1) \cdot Gcyl_cmd(n+d-1) \\ & - Ss \cdot Gcyl_cmd(n+d-2) \} \quad \dots (25) \end{aligned}$$

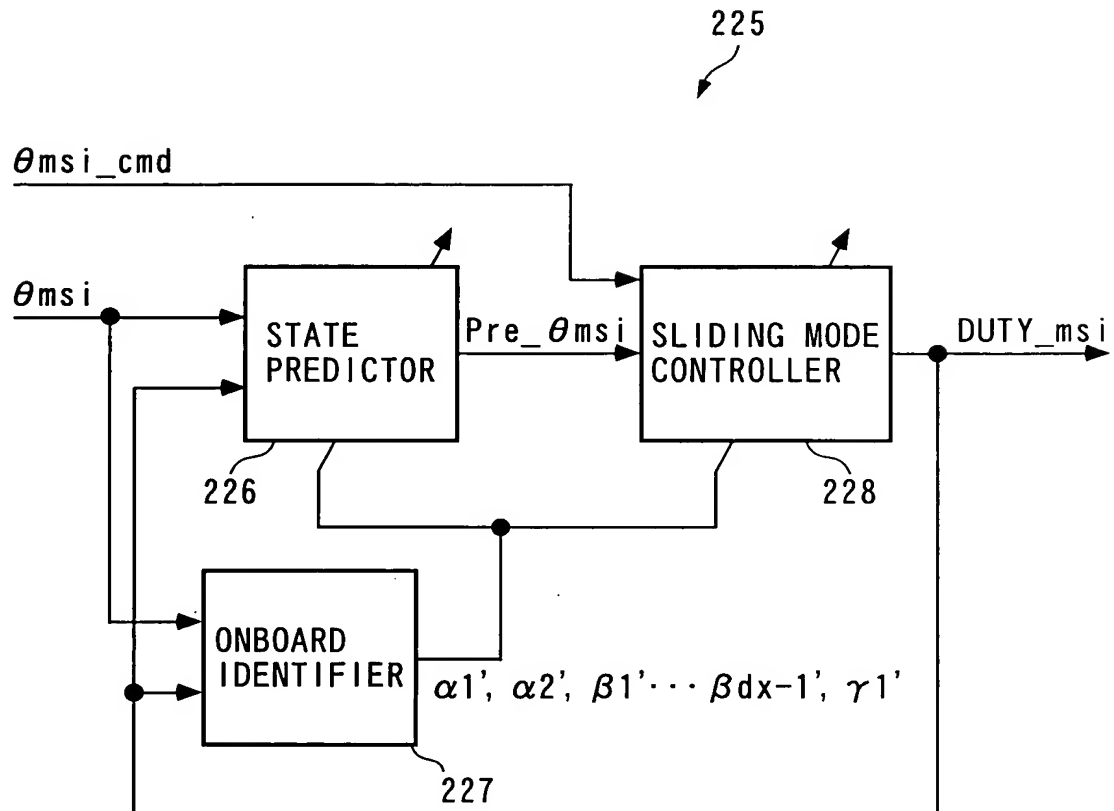
F I G . 2 8



F I G . 2 9



F I G. 3 0



F I G . 3 1

$$\theta_{msi}(m) = a1' \cdot \theta_{msi}(m-1) + a2' \cdot \theta_{msi}(m-2) + b1' \cdot DUTY_{msi}(m-dx) \quad \dots\dots (26)$$

$$A' = \begin{bmatrix} a1' & a2' \\ 1 & 0 \end{bmatrix} \quad \dots\dots (27)$$

$$B' = \begin{bmatrix} b1' \\ 0 \end{bmatrix} \quad \dots\dots (28)$$

$$\begin{aligned} Pre_ \theta_{msi}(m) &= \alpha1' \cdot \theta_{msi}(m) + \alpha2' \cdot \theta_{msi}(m-1) \\ &\quad + \beta1' \cdot DUTY_{msi}(m-1) + \beta2' \cdot DUTY_{msi}(m-2) \\ &\quad + \dots + \beta_{dx-1}' \cdot DUTY_{msi}(m-dx+1) + \gamma1' \\ &\doteq \theta_{msi}(m+dx-1) \quad \dots\dots (29) \end{aligned}$$

$\alpha1'$: FIRST-ROW FIRST-COLUMN ELEMENT OF A'^{dx-1}
 $\alpha2'$: FIRST-ROW SECOND-COLUMN ELEMENT OF A'^{dx-1}
 $\beta j'$: FIRST-ROW ELEMENT OF $A'^{j'-1} B'$ ($j' = 0 \sim dx-1$)

F I G . 3 2

$$\theta s'(m) = \theta s'(m-1) + KPs'(m) \cdot ide'(m) \quad \dots\dots (30)$$

$$KPs'(m) = \frac{Ps'(m) \cdot \zeta s'(m)}{1 + \zeta s'(m)^T \cdot Ps'(m) \cdot \zeta s'(m)} \quad \dots\dots (31)$$

$$Ps'(m+1) = \frac{1}{\lambda 1'} \left[I' - \frac{\lambda 2' \cdot Ps'(m) \cdot \zeta s'(m) \cdot \zeta s'(m)^T}{\lambda 1' + \lambda 2' \cdot \zeta s'(m)^T \cdot Ps'(m) \cdot \zeta s'(m)} \right] Ps'(m) \quad \dots\dots (32)$$

I' : UNIT MATRIX OF ORDER $dx+2$
 $\lambda 1', \lambda 2'$: WEIGHTING PARAMETER

$$\begin{aligned} ide'(m) &= Pre_ \theta msi(m-dx+1) - \theta msi(m) \\ &= \theta s'(m-1)^T \cdot \zeta s'(m) - \theta msi(m) \end{aligned} \quad \dots\dots (33)$$

$$\theta s'(m)^T = [\alpha 1', \alpha 2', \beta 1', \beta 2', \dots, \beta dx-1', \gamma 1'] \quad \dots\dots (34)$$

$$\begin{aligned} \zeta s'(m)^T &= [\theta msi(m-dx), \theta msi(m-dx-1), \\ &\quad DUTY_msi(m-dx), DUTY_msi(m-dx-1), \dots \\ &\quad \dots, DUTY_msi(m-2dx+2), 1] \end{aligned} \quad \dots\dots (35)$$

F I G . 3 3

$$Es'(m) = \theta_{msi}(m) - \theta_{msi_cmd}(m) \quad \dots\dots (36)$$

$$\sigma s'(m) = Es'(m) + Ss' \cdot Es'(m-1) \quad \dots\dots (37)$$

$$-1 < Ss' < 0 \quad \dots\dots (38)$$

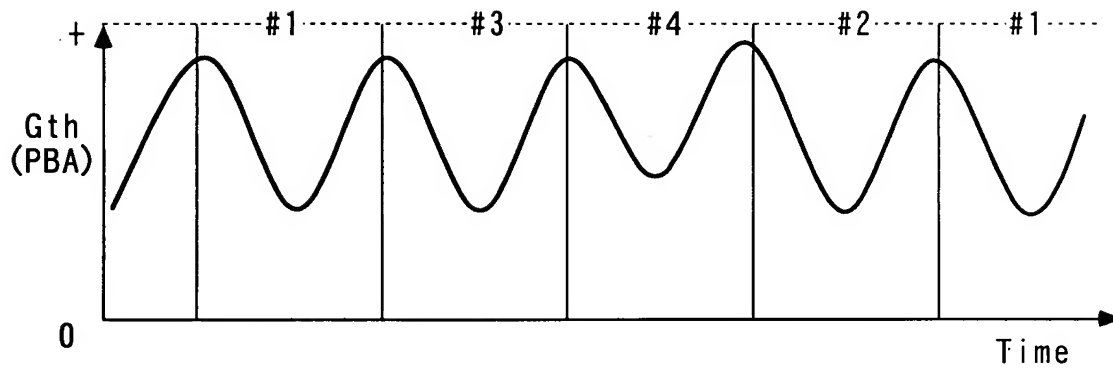
$$DUTY_{msi}(m) = U_{spas'}(m) = U_{eq'}(m) + U_{rch'}(m) \quad \dots\dots (39)$$

$$\begin{aligned}
 U_{eq'}(m) = & \frac{1}{\beta_1'} \{ Pre_ \theta_{msi}(m) + Ss' \cdot Pre_ \theta_{msi}(m-1) \\
 & - \alpha_1' \cdot Pre_ \theta_{msi}(m-dx+1) - \alpha_2' \cdot \theta_{msi}(m) \\
 & - \beta_2' \cdot DUTY_{msi}(m-1) - \dots - \beta_{dx-1}' \cdot DUTY_{msi}(m-dx+2) - \gamma_1' \\
 & + \theta_{msi_cmd}(m+dx) + (Ss'-1) \cdot \theta_{msi_cmd}(m+dx-1) \\
 & - Ss' \cdot \theta_{msi_cmd}(m+dx-2) \} \quad \dots\dots (40)
 \end{aligned}$$

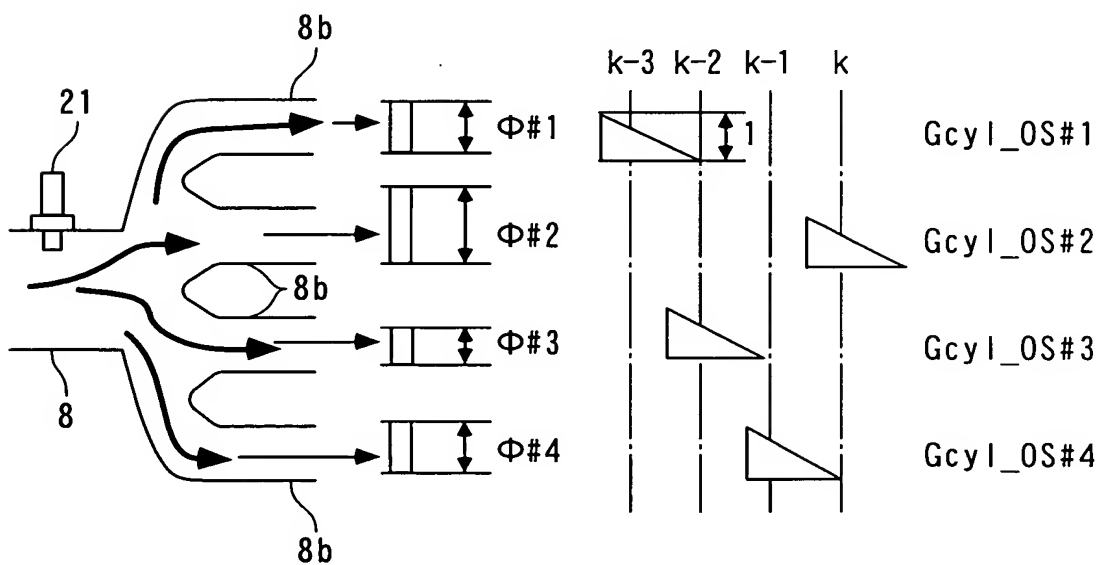
$$U_{rch'}(n) = \frac{-F'}{\beta_1'} \cdot \sigma s'(m+dx-1) \quad \dots\dots (41)$$

F' : REACHING LAW GAIN (0 < F' < 2)

F I G . 3 4



F I G . 3 5



F I G . 3 6

$$\begin{aligned} Gth(k-d') = & \Phi\#1(k) \cdot Gcyl_OS\#1(k) + \Phi\#2(k) \cdot Gcyl_OS\#2(k) \\ & + \Phi\#3(k) \cdot Gcyl_OS\#3(k) + \Phi\#4(k) \cdot Gcyl_OS\#4(k) \\ & \dots\dots (42) \end{aligned}$$

$$\begin{aligned} Gth_est(k) = & \Phi\#1(k) \cdot Gcyl_OS\#1(k) + \Phi\#2(k) \cdot Gcyl_OS\#2(k) \\ & + \Phi\#3(k) \cdot Gcyl_OS\#3(k) + \Phi\#4(k) \cdot Gcyl_OS\#4(k) \\ & \dots\dots (43) \end{aligned}$$

$$\phi(k) = \phi(k-1) + KR(k) \cdot ide'(k) \quad \dots\dots (44)$$

$$KR(k) = \frac{R(k) \cdot \zeta'(k)}{1 + \zeta'(k)^T \cdot R(k) \cdot \zeta'(k)} \quad \dots\dots (45)$$

$$ide'(k) = Gth(k-d') - Gth_est(k) \quad \dots\dots (46)$$

$$Gth_est(k) = \phi(k-1)^T \zeta'(k) \quad \dots\dots (47)$$

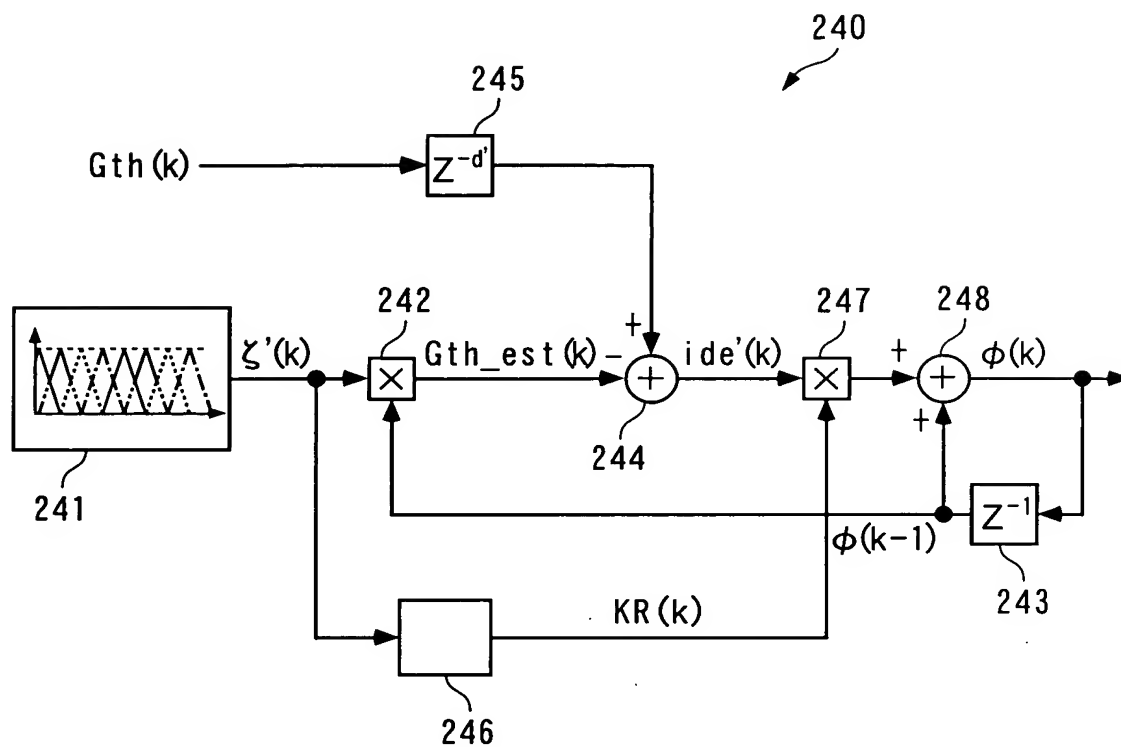
$$R(k+1) = \frac{1}{\lambda 1''} \left[I - \frac{\lambda 2'' \cdot R(k) \cdot \zeta'(k) \cdot \zeta'(k)^T}{\lambda 1'' + \lambda 2'' \cdot \zeta'(k)^T \cdot R(k) \cdot \zeta'(k)} \right] R(k) \quad \dots\dots (48)$$

I: UNIT MATRIX
 $\lambda 1''$, $\lambda 2''$: WEIGHTING PARAMETER

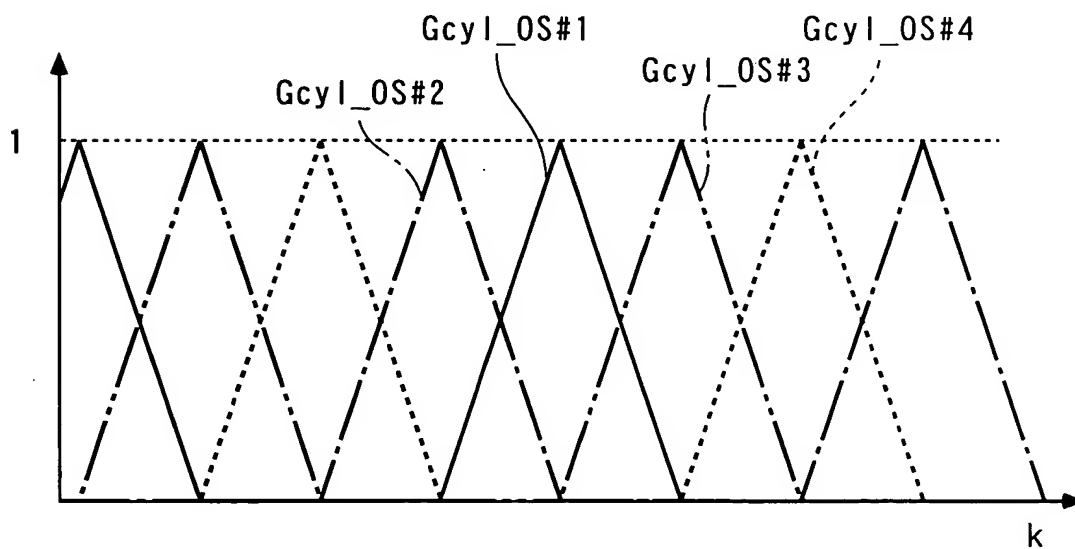
$$\phi(k)^T = [\Phi\#1(k), \Phi\#2(k), \Phi\#3(k), \Phi\#4(k)] \quad \dots\dots (49)$$

$$\begin{aligned} \zeta'(k)^T = & [Gcyl_OS\#1(k), Gcyl_OS\#2(k), Gcyl_OS\#3(k), Gcyl_OS\#4(k)] \\ & \dots\dots (50) \end{aligned}$$

F I G . 3 7



F I G . 3 8



F I G. 3 9

$$E\Phi\#i(k) = \Phi\#i(k) - \Phi\#1(k) \quad \dots\dots (51)$$

$$(i = 2 \sim 4)$$

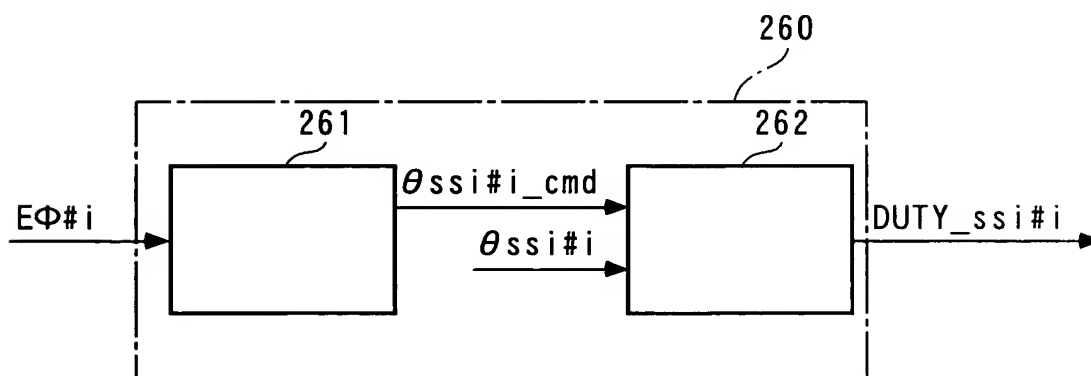
$$\sigma'(k) = E\Phi\#i(k) + S'E\Phi\#i(k-1) \quad \dots\dots (52)$$

$$\theta_{ss\#i_cmd}(k) = -Fs' \cdot \sigma'(k) - Gs' \cdot \sum_{j=0}^k \sigma'(j) - Hs' \cdot E\Phi\#i(k) \quad \dots\dots (53)$$

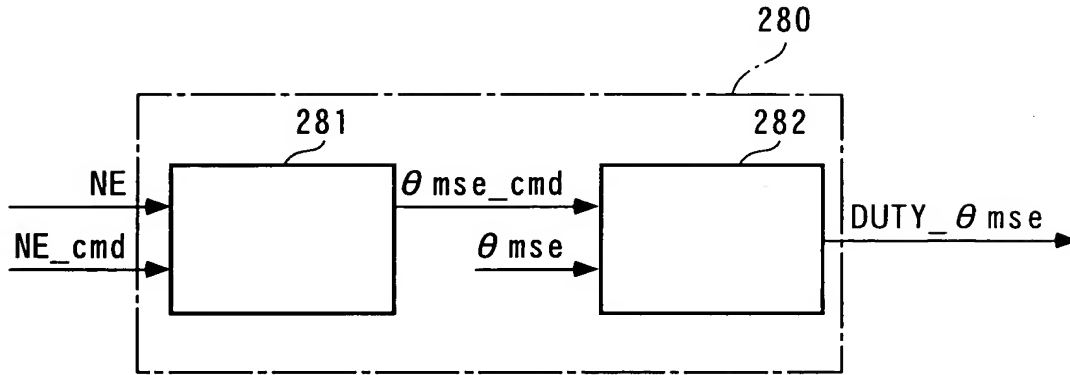
Fs' , Gs' , Hs' : FEEDBACK GAIN

S' : SWITCHING FUNCTION-SETTING PARAMETER ($-1 < S' < 1$)

F I G. 4 0



F I G . 4 1



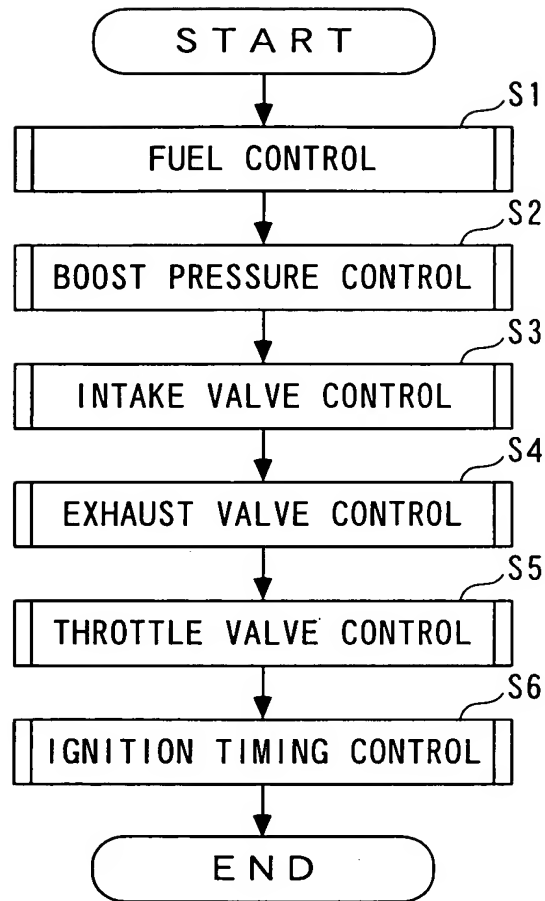
F I G . 4 2

$$\theta_{mse_cmd}(n) = \theta_{mse_ast}(n) + d\theta_{mse}(n) \quad \dots\dots (54)$$

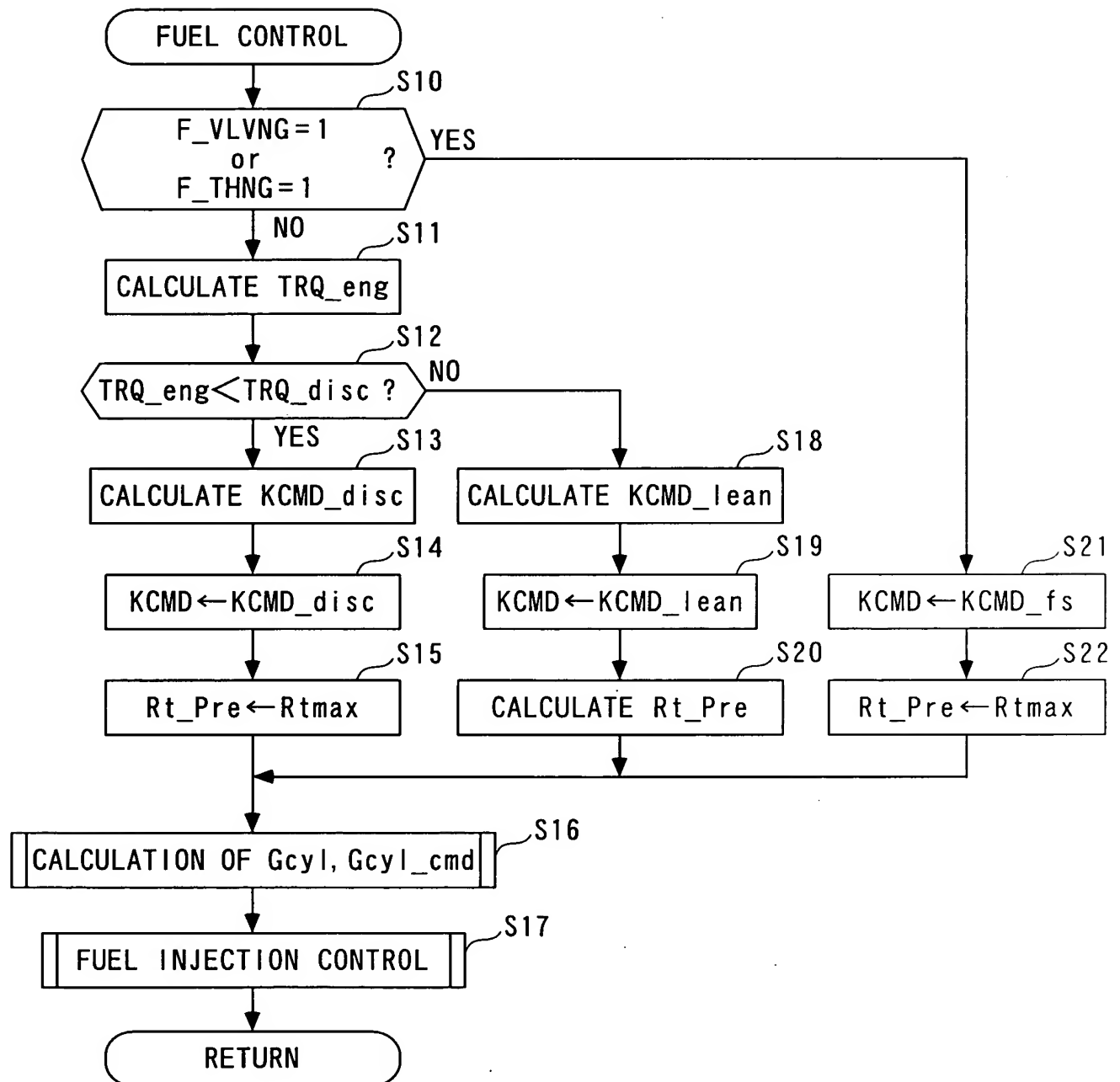
$$d\theta_{mse}(n) = -K_{astr} \cdot \sigma_{ast}(n) + \left[-K_{asta} \cdot \sum_{i=0}^n \sigma_{ast}(i) \right] \quad \dots\dots (55)$$

$$\sigma_{ast}(n) = NE(n) - NE_cmd(n) + S_{ast} \cdot [NE(n-1) - NE_cmd(n-1)] \quad \dots\dots (56)$$

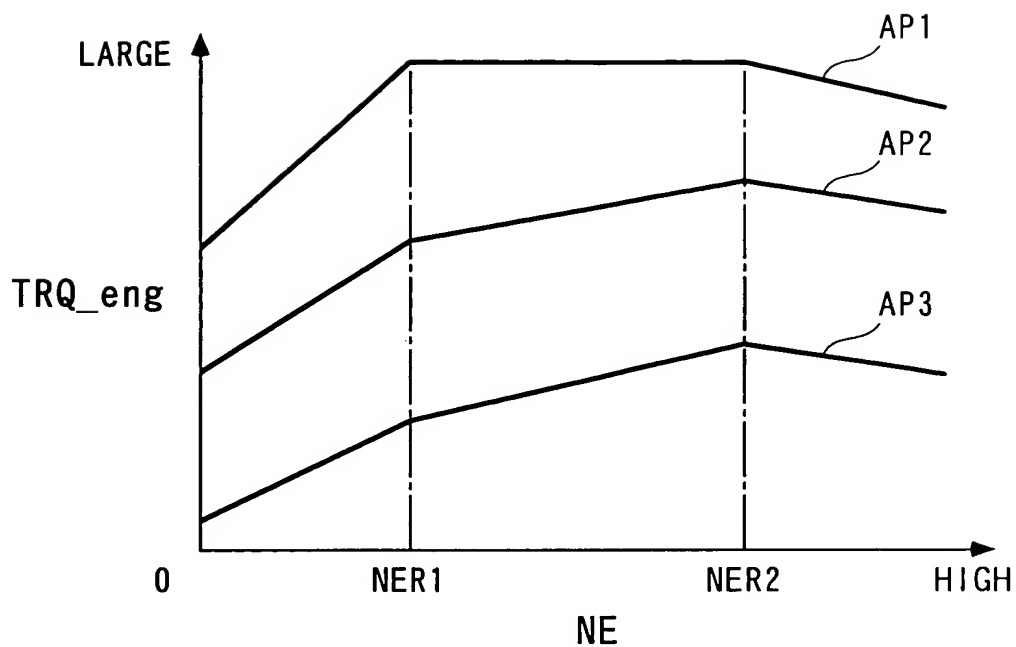
F I G . 4 3



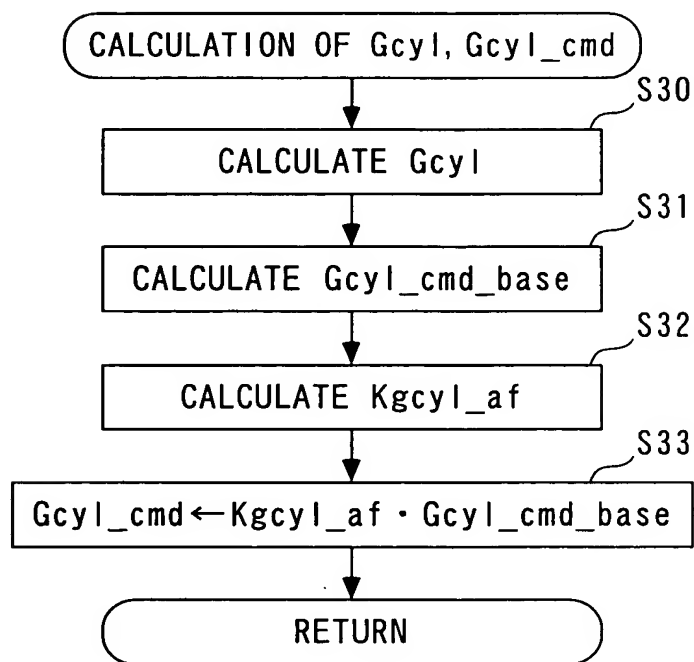
F I G . 4 4



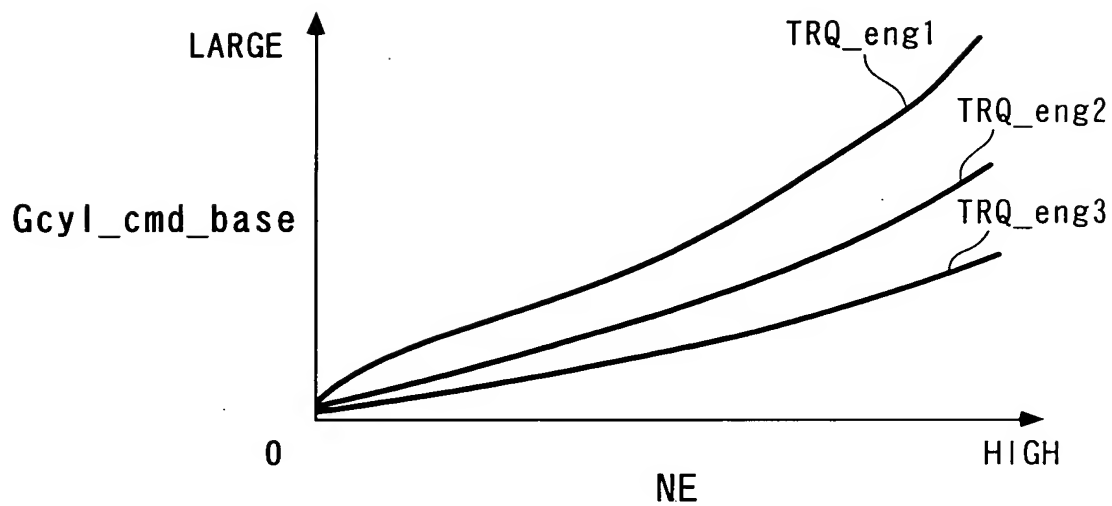
F I G. 4 5



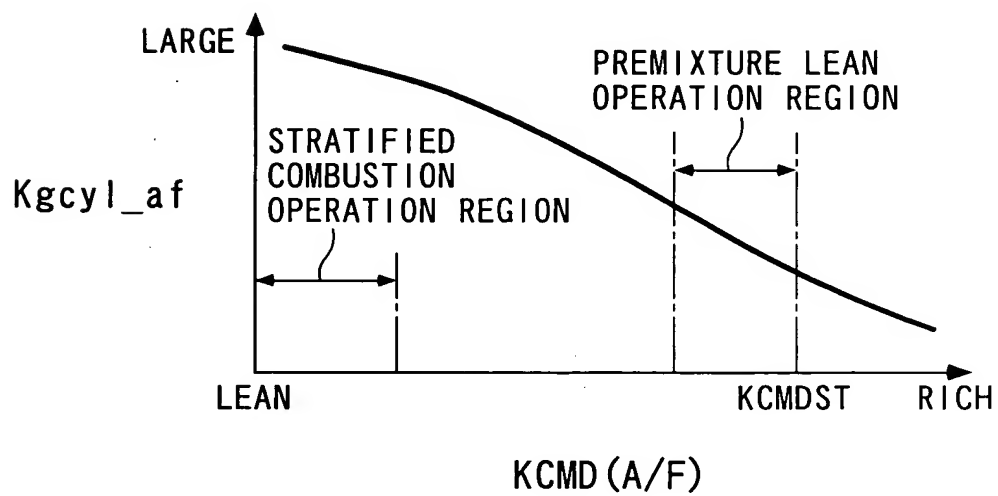
F I G. 4 6



F I G . 4 7



F I G . 4 8



F I G . 4 9

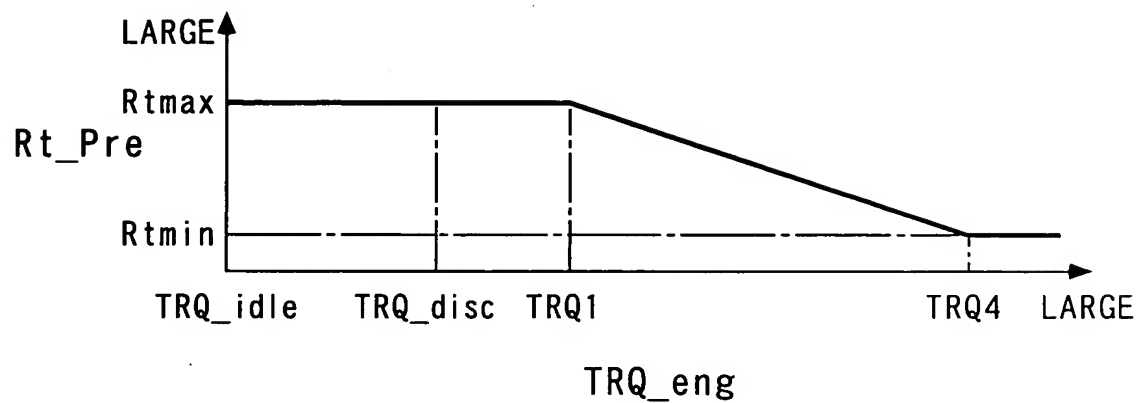
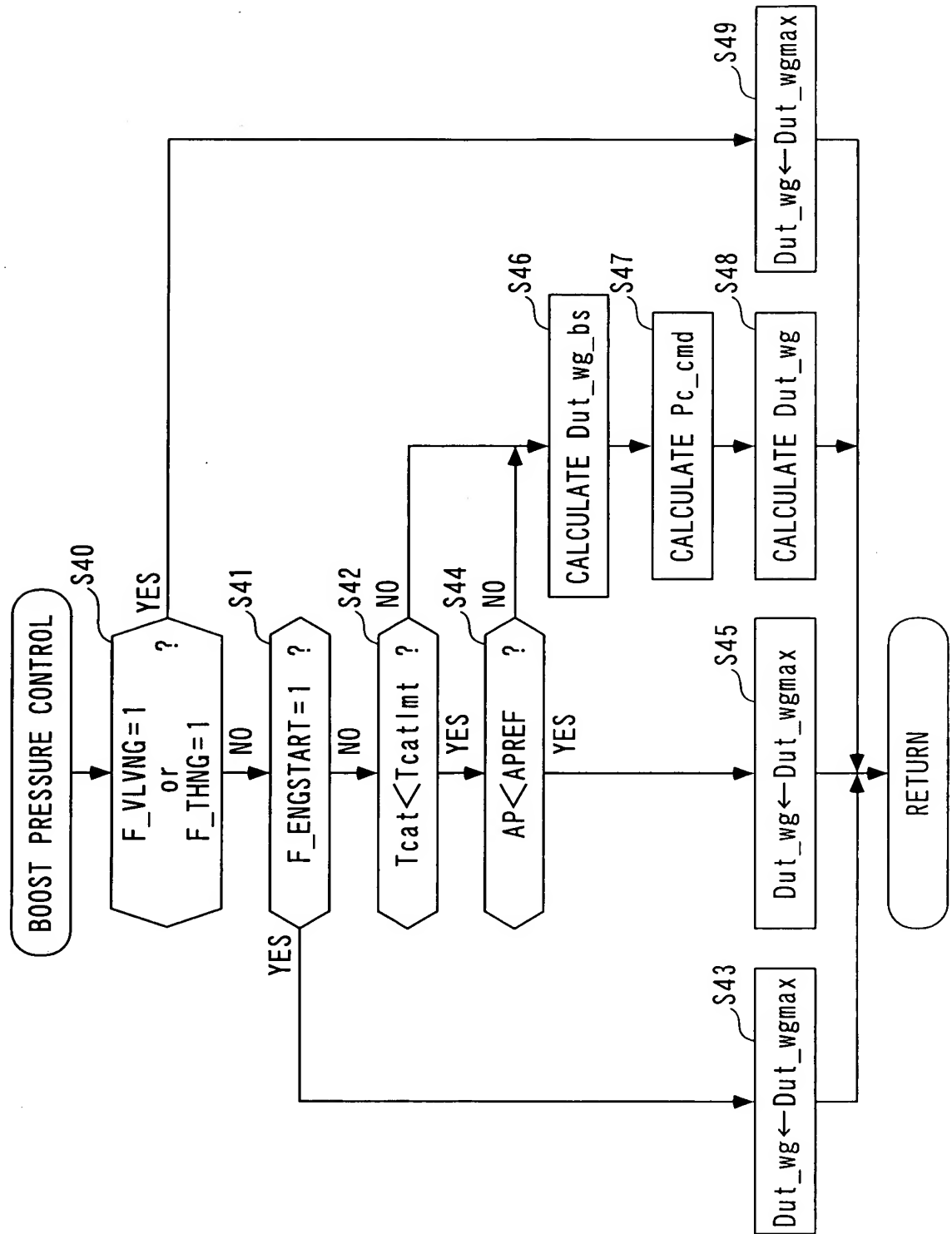
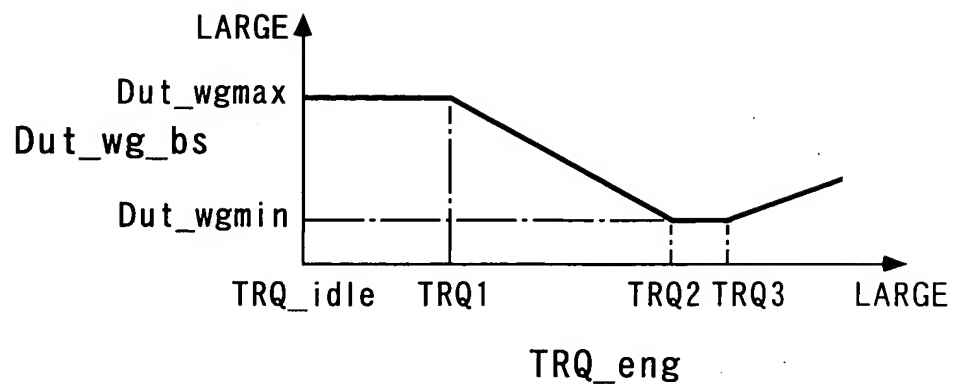


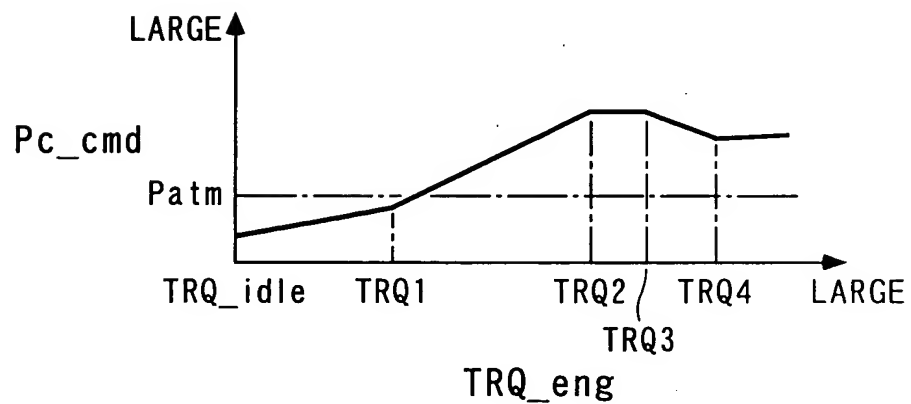
FIG. 50



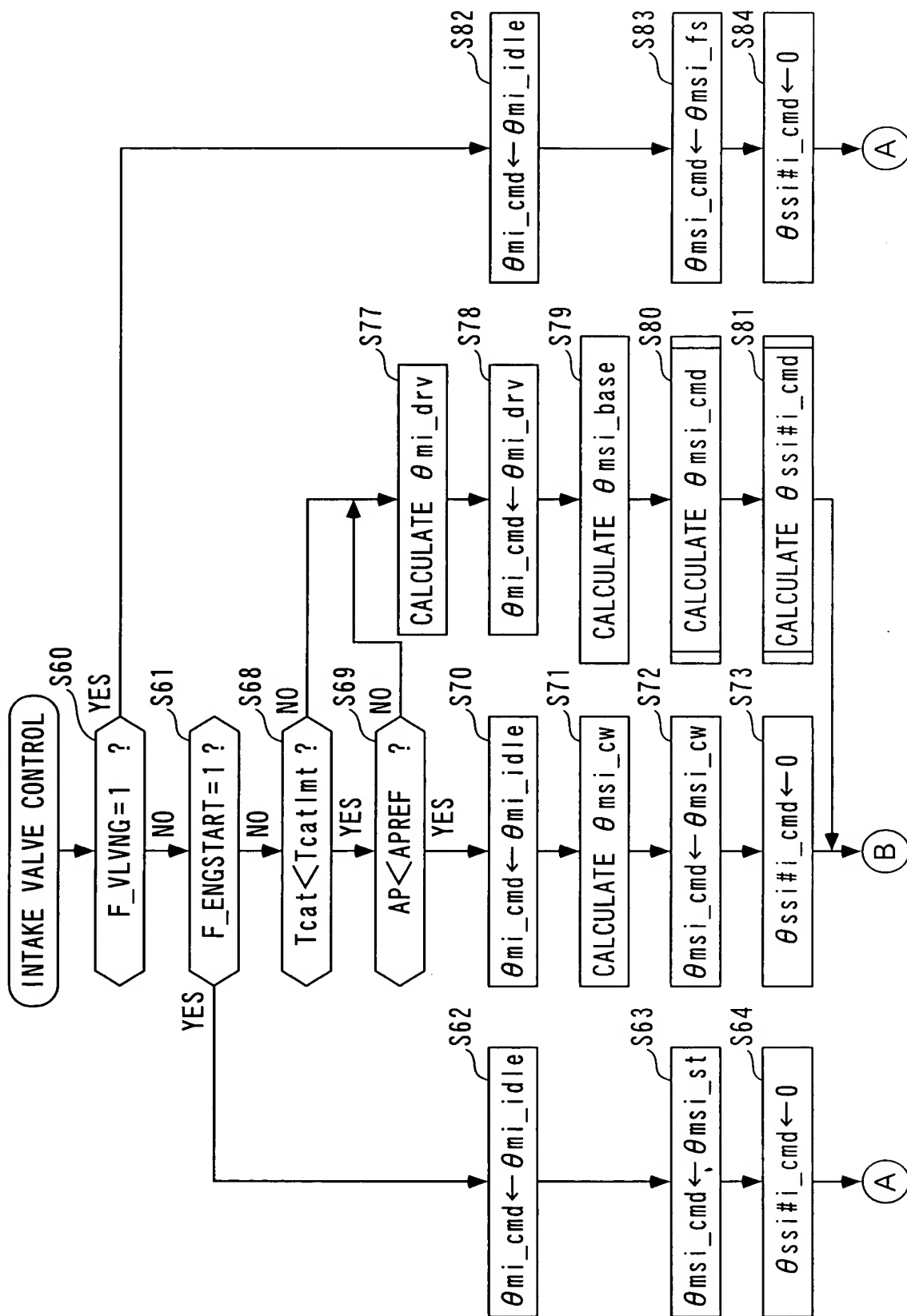
F I G . 5 1



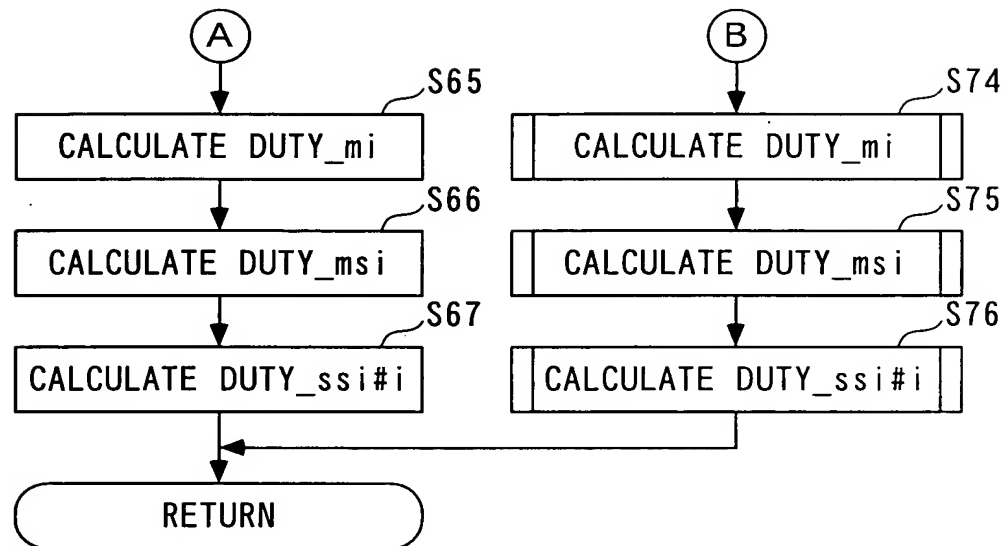
F I G . 5 2



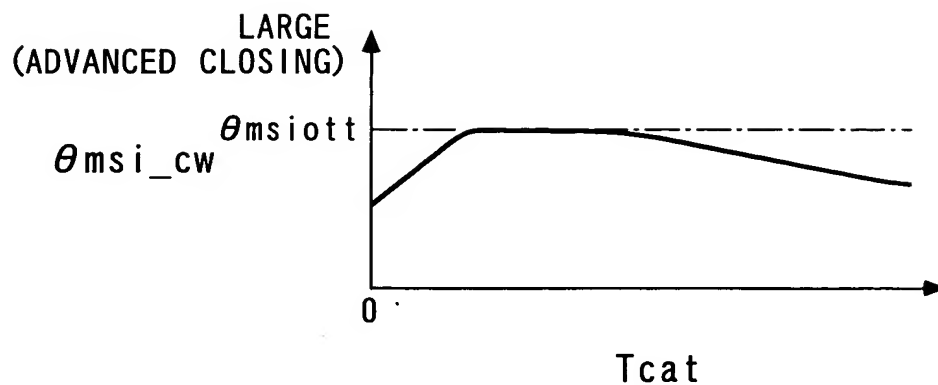
F I G. 5 3



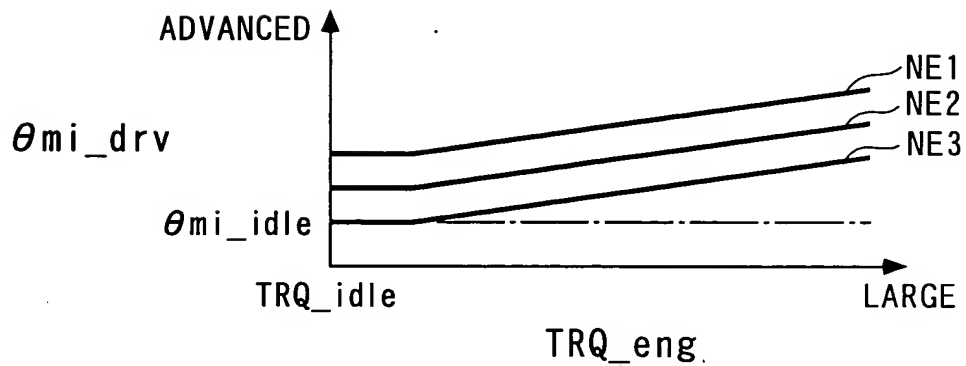
F I G . 5 4



F I G. 5 5



F I G. 5 6



F I G . 5 7

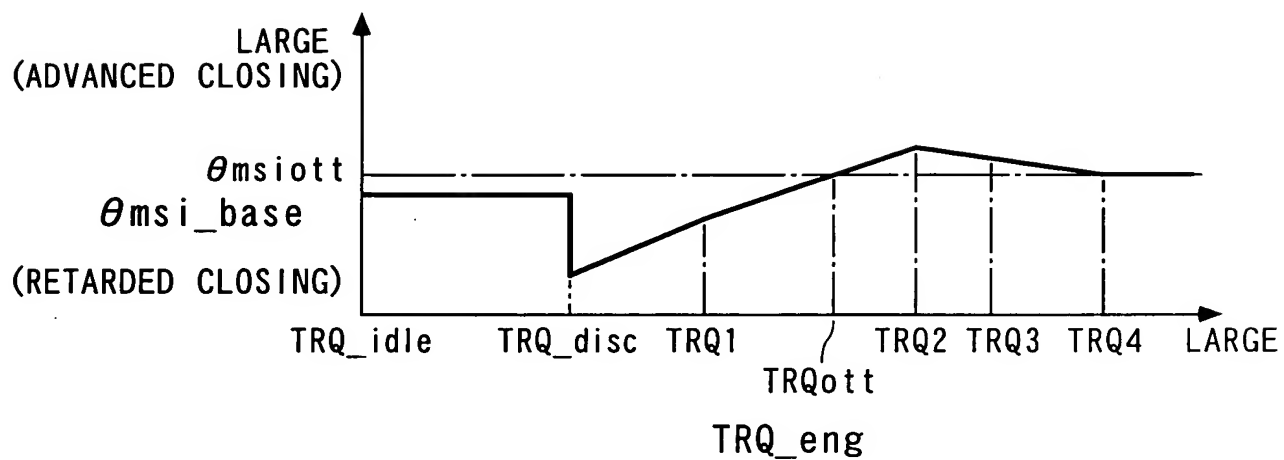
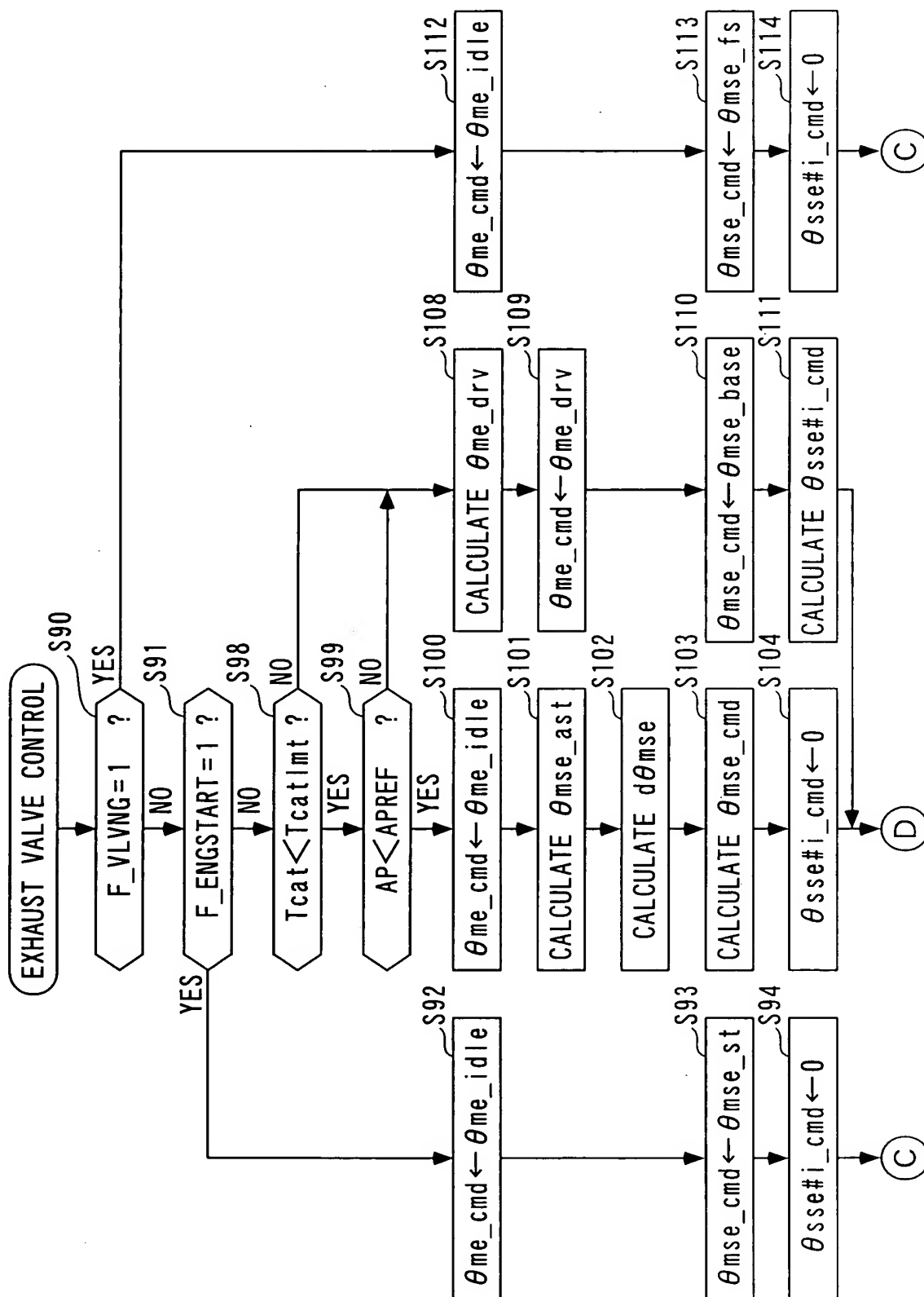
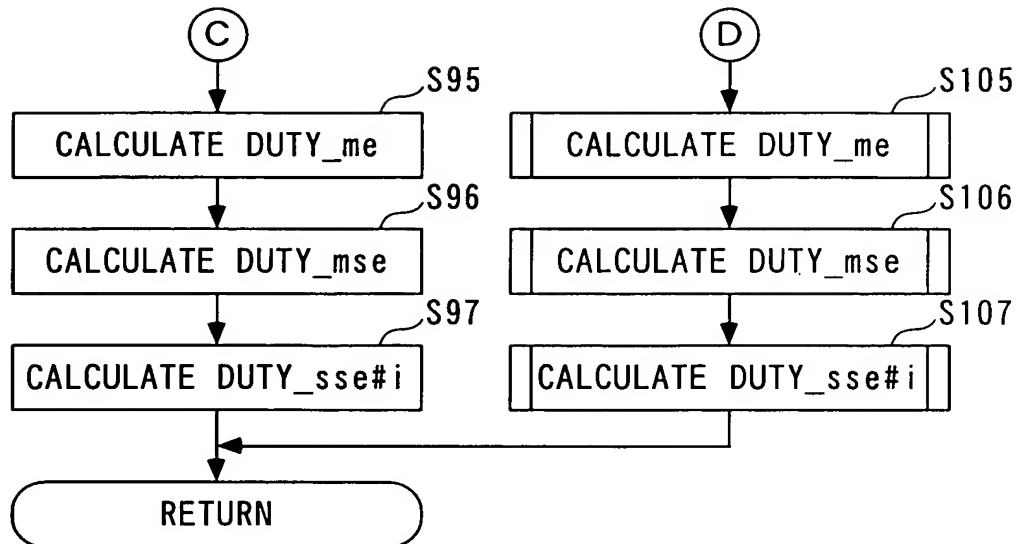


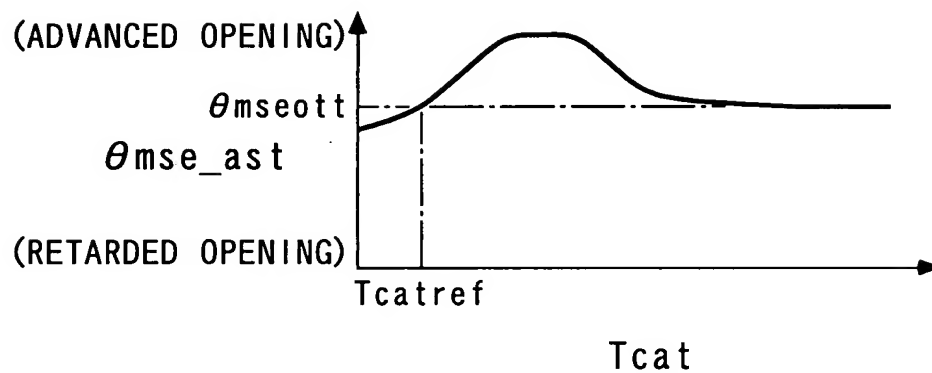
FIG. 58



F I G . 5 9



F I G . 6 0



F I G . 6 1

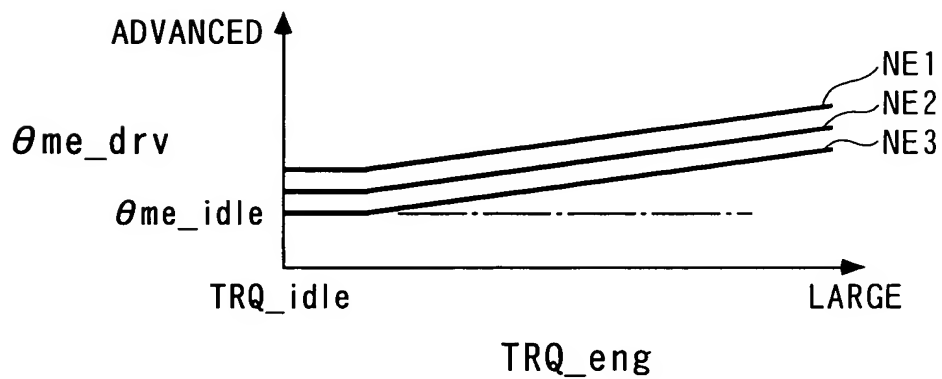
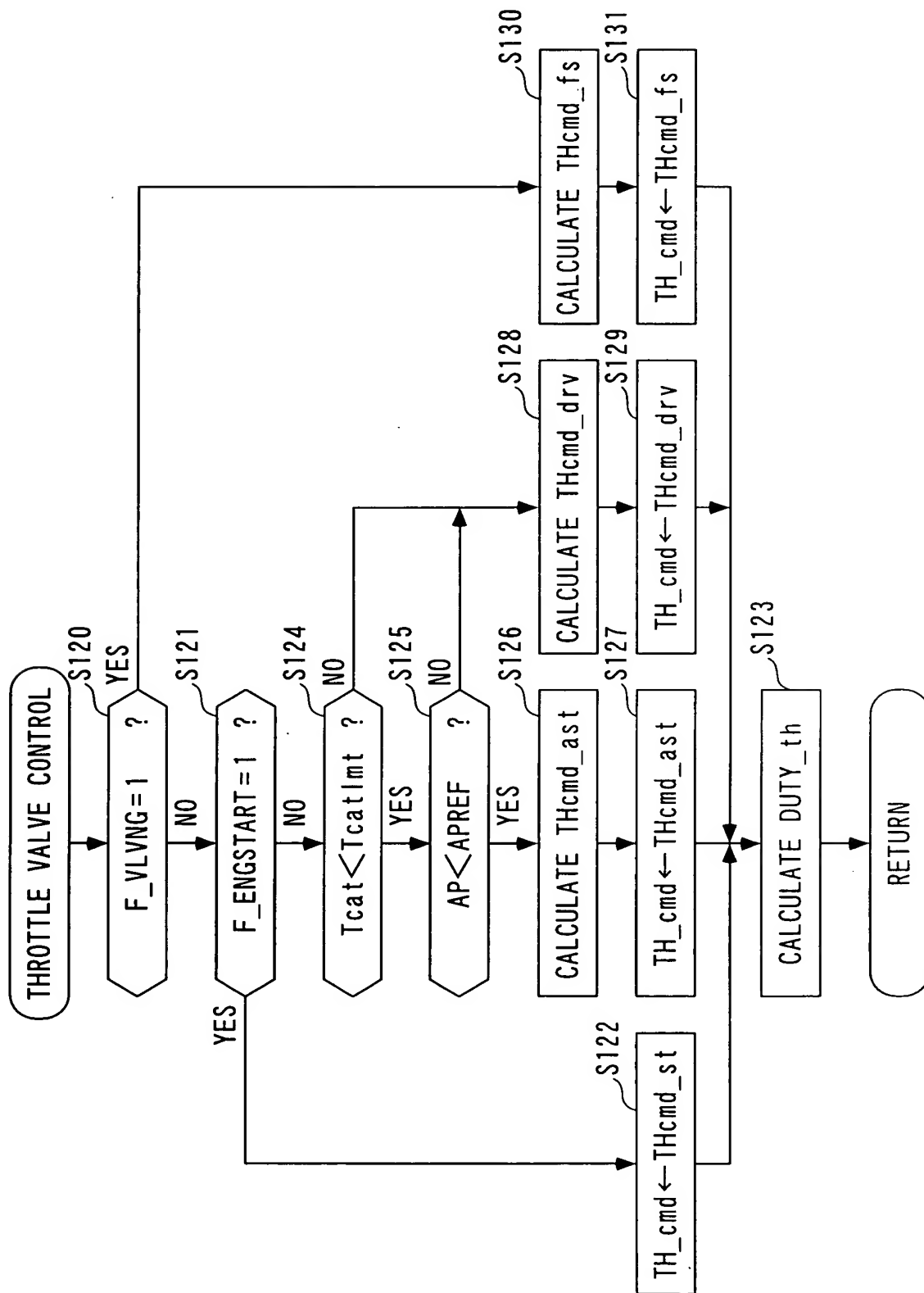
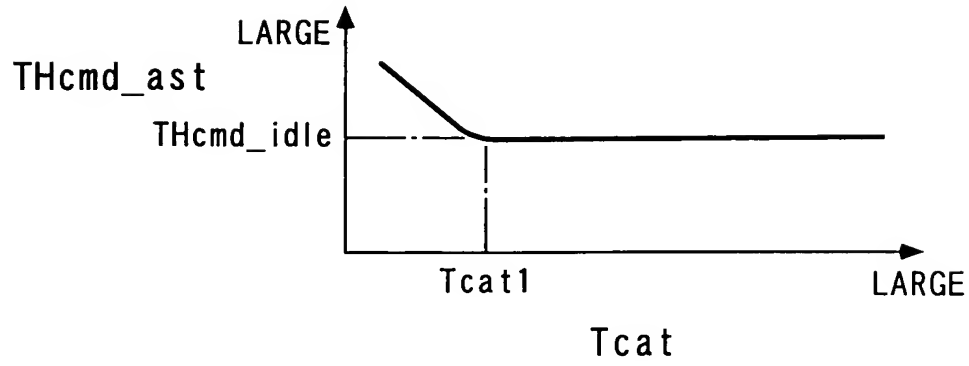


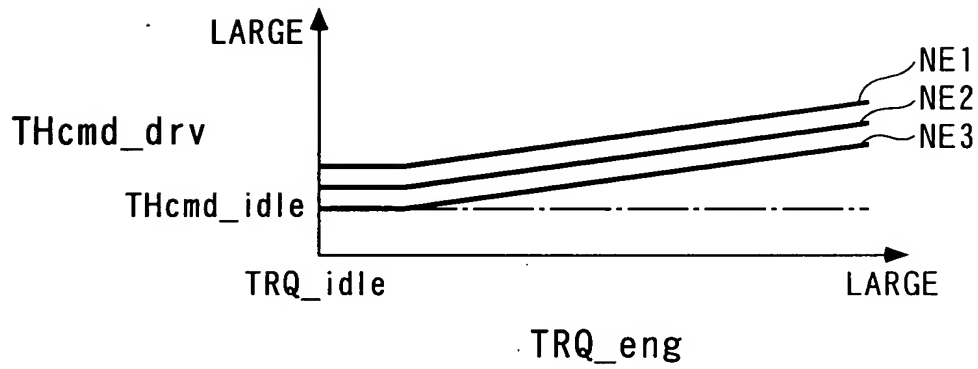
FIG. 62



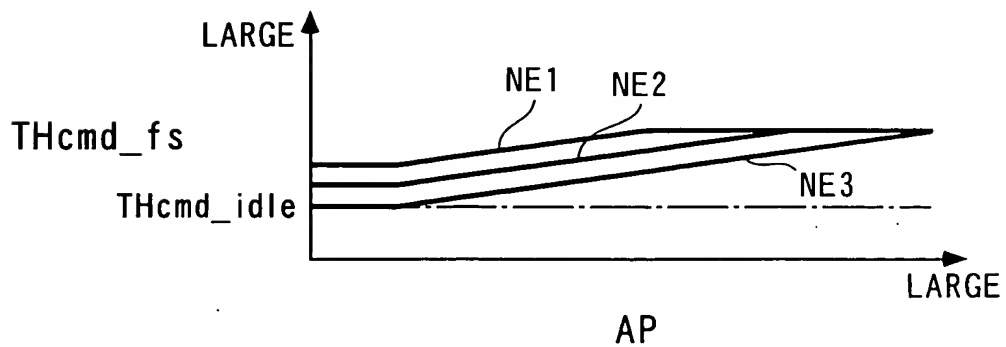
F I G. 6 3



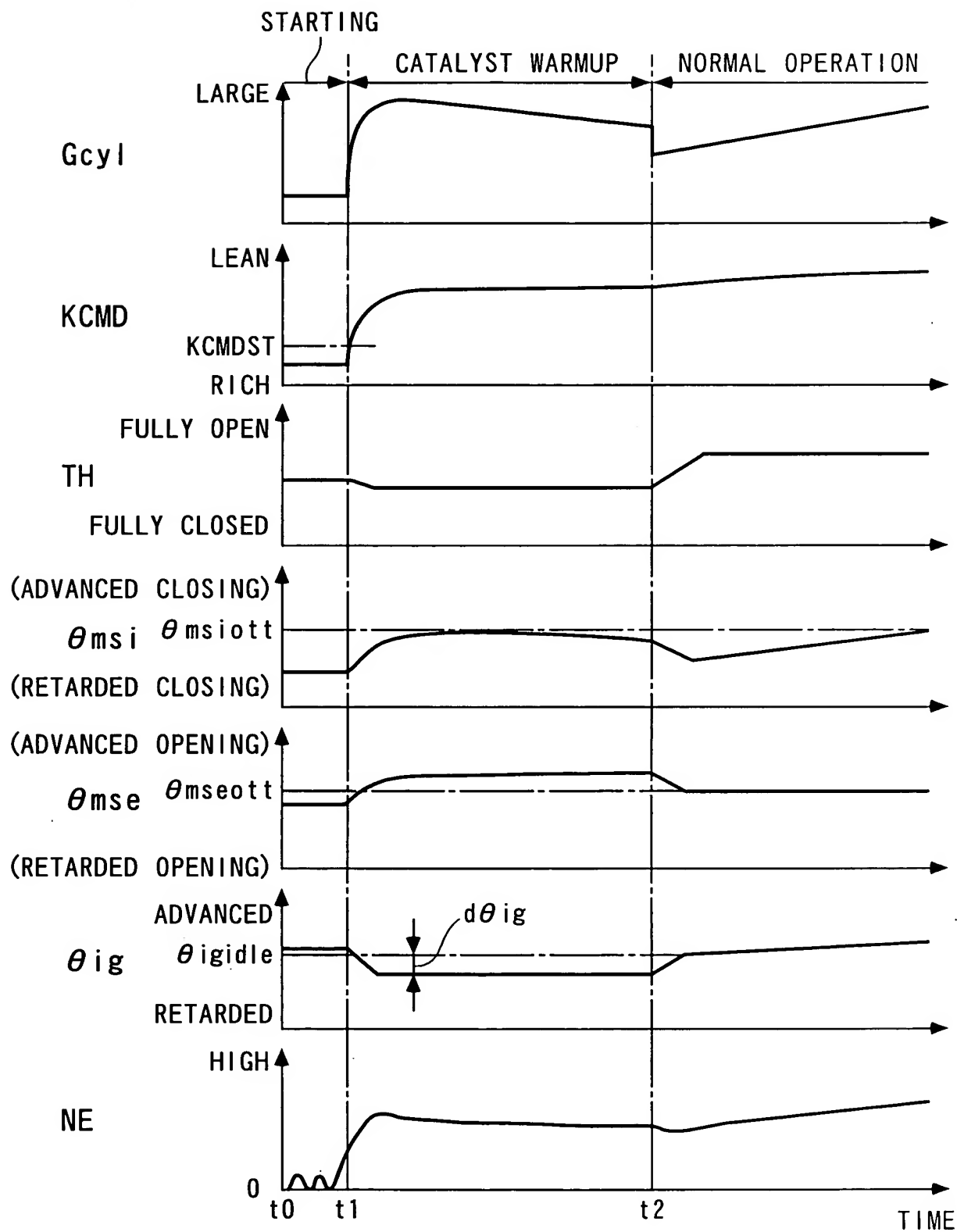
F I G. 6 4



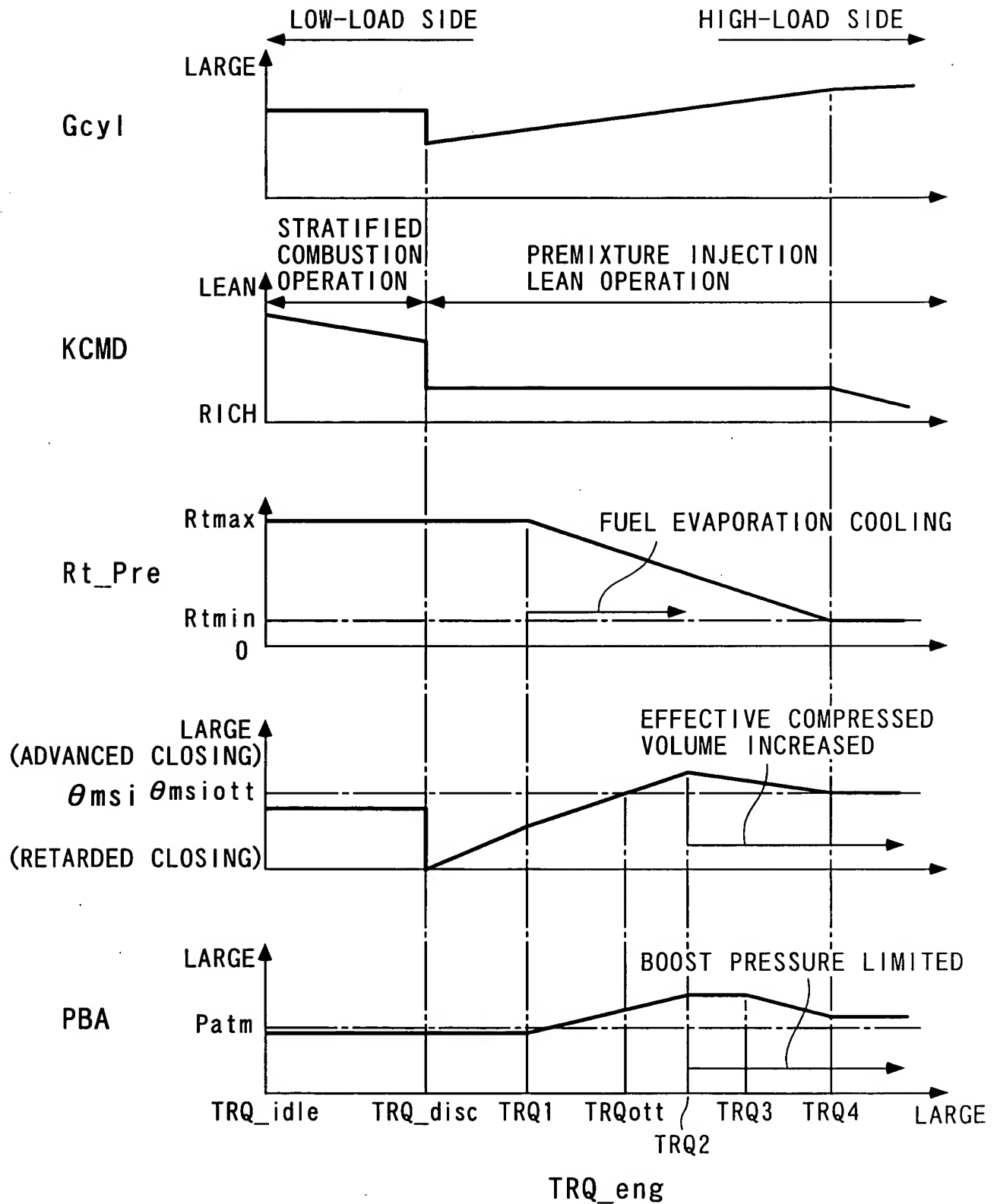
F I G. 6 5



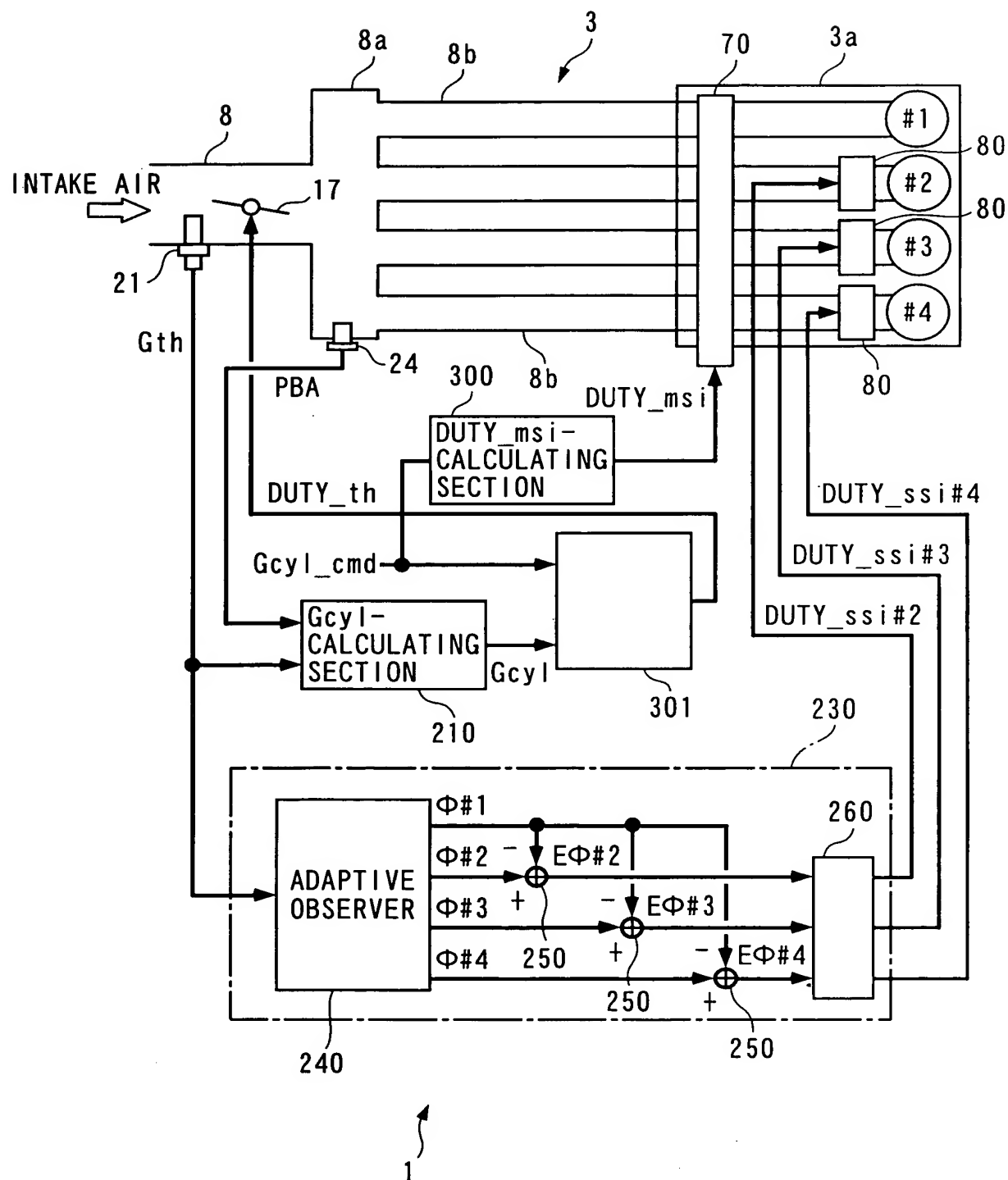
F I G. 6 6



F I G. 6 7



F I G. 6 8



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